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Original Research

Sedentary Behavior Patterns After ACL Reconstruction

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Abstract

International Journal of Exercise Science 18(4): 636-658, 2025. https://doi.org/10.70252/UWHV9758 Individuals after anterior cruciate ligament reconstruction (ACLR) are less physically active than their uninjured peers, but little is known about their sedentary behavior (SB). This study aimed to identify patterns of SB in individuals six and 18 months after ACLR. Eighteen individuals after ACLR wore accelerometers for one week during six- and 18-month post-operative assessments (83.3% female, 19.7±5.6 years old, BMI 23.9±kg/m²). The percentage of awake time spent in SB was estimated. A multilevel (two time points – six and 18 months), multidimensional (13 hours) functional principal component analysis generated two sets of unique personalized principal component scores: between-participant (person level principal components, PPC) and within-participant (follow-up level principal components, FPC). An exploratory analysis compared SB patterns with structural and symptomatic signs of knee health outcomes. Participants averaged 65.4±7.5% and 65.7±9.0% time in SB at six and 18 months after ACLR, respectively. The first PPC identified an overall pattern of high levels of SB throughout the day. The first FPC identified a pattern of decreased SB in the morning and increased SB in the evening 18 months after ACLR compared to six months. Our exploratory analysis identified a potential association between this first FPC and knee health symptoms 18 months after ACLR. Different SB patterns existed six months after ACLR. Our findings suggest the time of day when individuals after ACLR are most sedentary and provide a foundation to develop and test interventions to reduce time in SB by substituting periods of physical activity.

Keywords: Physical activity, outcomes, exercise

Introduction

Anterior cruciate ligament (ACL) injuries are common, with up to 200,000 each year within the United States.[1] Current practice within the United States includes surgical ACL reconstruction

(ACLR), which increased by 22% from 2002 to 2014.[2] While surgery improves passive knee stability,[3] it does not alter the risk of early development of knee osteoarthritis (OA)[4] related symptoms. Up to 54% of individuals report symptoms related to knee dysfunction within 6 months of ACLR,[5] and up to 82% of individuals have structural signs of knee OA on radiographs within 15 years of injury.[6] In addition to radiography, quantitative magnetic resonance imaging (MRI) has been used to identify signs of OA in individuals even by six months after ACLR.[7] Early onset knee OA is troubling, as individuals with OA contribute up to $185 billion in annual healthcare costs in the United States alone.[8] To reduce the individual and societal burden of knee OA in individuals who have had an ACLR, it is vital to develop therapeutic interventions to reduce the risk and progression of OA after injury.

Physical activity (PA) participation is a modifiable risk factor for OA that may guide the development of interventions to prevent OA after ACLR.[9] While studies show that PA participation is not directly related to radiographically assessed structural OA development in individuals at risk of OA,[10,11] multiple large cohort studies have linked physical inactivity to OA symptoms.[12-14] Participation in sedentary behavior (SB) is also high in individuals with knee OA.[15] Increased time in SB is related to reduced knee function,[12] and other health outcomes such as cardiovascular disease and all-cause mortality.[16] Structurally, signs of OA present on MRI are associated with PA participation within one month of ACL injury[17] and six to 12 months after ACLR.[18] With the established relationship between PA and OA in older individuals, a relationship between PA and OA risk in individuals after ACLR may also be present.

Although PA participation can be beneficial for the management of OA-related symptoms, individuals with an ACLR continue to regularly participate in less PA than their uninjured peers.[19,20] Six to 36 months after ACLR, individuals walk 1500 to 3000 fewer steps per day [19,20] and spend almost 15 fewer minutes per day in moderate-to-vigorous PA compared to than their uninjured peers.[19] Improving time in PA among individuals after ACLR may mitigate progression to knee OA and contribute to improvements in general health after injury. However, to date, no intervention has successfully increased PA in these individuals.[21]

To guide the development of effective PA interventions after ACLR, an understanding of daily movement patterns (PA and SB) in individuals after ACLR is needed. Identifying times of day when individuals may be participating in more SB would allow for directed interventions to reduce time spent in SB by replacing these periods with some level of PA. For instance, adults over the age of 63 years of age with hip and knee OA spend large proportions of time in SB during the day, steadily increasing the proportion of time in SB from morning to afternoon to evening.[22] Using this knowledge, interventions can be tested that break up periods of SB throughout the day, particularly in the evening.

As individuals after ACLR are typically younger than individuals with primary hip and knee OA and have different life demands, such as school, work, or childcare needs, different daily movement patterns will likely be present compared to older adults. For instance, younger individuals may have more opportunities to engage in recreational PA compared to adults with full-time employment, which could result in younger individuals having less SB than older individuals. Therefore, the purpose of this study was to identify daily patterns in SB in individuals six and 18 months after ACLR. We hypothesized that there would be distinct patterns of SB observed in individuals six and 18 months after ACLR. An additional exploratory analysis was performed to compare SB pattern types with structural and symptomatic signs related to knee OA after ACLR.[23] Structural signs related to knee OA were assessed using quantitative MRI, while symptoms related to knee OA were assessed using a combination of patient-reported outcome measures and objectively measured knee function.

Methods

Participants in the study were assessed six and 18 months after ACLR. Six months after ACLR, SB was assessed along with quantitative MRI, specifically T2 relaxation time. Eighteen months after ACLR, SB and quantitative MRI were assessed again, as was patient-reported knee function and objectively measured knee function.

Participants

This is an analysis of a group of individuals from a prospective cohort study with up to 18 months of follow-up after ACLR. There were 29 individuals eligible for 18-month follow-up, 18 of which had complete data through 18 months after ACLR. Individuals not included in this study were either missing SB data (n=8), had moved out of state (n=2), or had withdrawn prior to study completion (n=1). Individuals were included in the initial cohort study if they were between the ages of 15 and 35 years and able to enroll within one month of their ACL injury, but before undergoing an ACLR. Individuals were excluded if they had previous serious injury or surgery to either knee, concomitant grade III tear to other knee ligaments requiring surgical intervention, anticipated meniscectomy by treating orthopedic surgeon, chondral lesions or degenerative cartilage changes noted on pre-operative MRI, or open growth plates altering the ACLR technique. Additional exclusion criteria were history of inflammatory disease, immunocompromise, chronic use of nonsteroidal anti-inflammatory medications (per self-report of at least 3 months of persistent use prior to enrolling in the study), cortisone injection to the knee within the previous three months, current pregnancy, or any contraindications for MRI. All participants at least 19 years old provided written informed consent (minor provide assent with written informed consent from a parent or legal guardian) as approved by the Institutional Review Board of the University of Nebraska Medical Center. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science.*[24]

Protocol

Objectively Assessed Sedentary Behavior.

One week of SB during waking hours was measured at 100 Hz using a reliable and valid waist-worn, 3-axis accelerometer (Actigraph wGX-BT) at both six and 18 months after ACLR.[25] A valid week of wear required at least ten hours of wear for at least four of the seven days. This accelerometer measures movement, called activity counts. These activity counts are then used to identify non-wear time, wear time, and activity intensity. Non-wear time was defined as any period of at least 90 consecutive minutes with no activity counts. Data were downloaded and processed in ActiLife software (ActiLife v6.13.4, ActiGraph Corp Pensacola, FL). Each minute of wear was categorized as SB if activity counts were less than 100[26] and assessed throughout each day. Each day was divided into 24 individual hours. As the outcome of interest was percentage of time spent in SB for each individual hour, any hour having fewer than 40 minutes of wear time was excluded. Excluding any hour with fewer than 40 minutes of wear time was done to ensure an hour was representative of a participant's SB. All participants in this study had some data missing between the hours of 7:00 am to 9:00 am; therefore, SB levels during the 7:00 am, 8:00 am, and 9:00 am hours were averaged for each participant. The same approach was taken for the hours of 9:00 pm to 11:00 pm. The hours from 12:00 am to 7:00 am were excluded, as most individuals did not wear the activity monitor for any portion of this time period. Once the percentage of SB for each individual hour was calculated for each day of valid wear, SB during each hour was averaged across all valid days of wear for each individual.

Structural Osteoarthritis.

Quantitative MRI, specifically T2 relaxation time, was used to assess structural signs of early onset knee OA. A higher T2 relaxation time indicates a higher water content or more disorganized cartilage structure, signifying worse cartilage health. T2 relaxation time in the tibiofemoral cartilage was measured at six and 18 months after ACLR, with percent change between six and 18 months after ACLR as the variable of interest. The MRI procedure has been previously described.[17] Briefly, MRI collection occurred after a 30-minute unloading period in sitting by each participant. A spin echo sequence was acquired (Repetition Time = 2700 ms; 10 echoes with the echo times at 10 ms increments starting from 10 ms [10, 20, 30,…100)]; Field of View: 120 x 120 mm^2; Acquisition Matrix = 252 x 250; Slice Thickness = 3.0 mm; Slice Gap = 0.5 mm; Range of Slices = 23-31; Pixel Size = 0.3125 x 0.3125; Echo Train Length = 10; Number of Averages = 1). Multi-echo MRI data were fit at each pixel using the signal equation $S_i = S_0 \exp(-TE_i / T_2)$. [$S_0$ = signal at echo time = 0. TE_i = i^{th} echo time]. T2 maps were then generated using Levenberg-Marquardt nonlinear least squares algorithm. All MRI data was confirmed by a fellowship-trained, board-certified musculoskeletal radiologist with 20 years of clinical experience. The medial and lateral tibiofemoral compartments were identified using the center of the intercondylar notch, followed by manual identification of the cartilage of the femur, tibia, and patella. The weightbearing region of the femur and tibia was then identified using ITK-Snap software.[27] The weightbearing regions of the femur and tibia were defined by the region between the anterior and posterior borders of the meniscal horns (Figure 1).

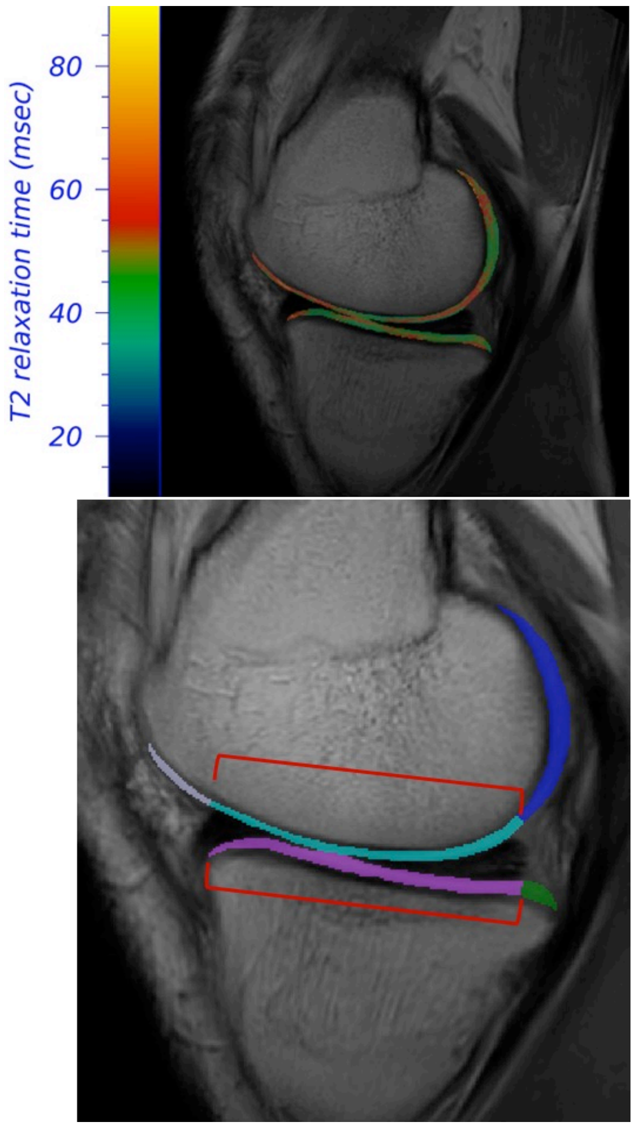

Figure 1. MRI of a participant demonstrating: a) pixel by pixel T2 relaxation map, and b) articular cartilage regions of interest (teal is weightbearing portion of femoral cartilage, pink is weightbearing portion of tibial cartilage).

Symptomatic OA.

Patient-Reported Knee Symptoms and Function.

Participants completed the International Knee Documentation Committee Subjective Knee Form 2000 (IKDC) in-person at 18 months after ACLR. The IKDC is a valid and reliable assessment of pain, symptoms, and function.[28] The IKDC uses a scale of 0-100%, with higher values representing better knee function. Various cutoff scores for the IKDC have been proposed and used to identify adequate patient-reported knee function. Because the individuals in the current study were further out from ACLR than many of the studies with recommendations, the highest cutoff score of 90% was selected to define adequate patient-reported knee function.[29] Individuals who scored under 90% at 18 months after ACLR were categorized as having inadequate patient-reported knee function, while those at or above 90% were categorized as having adequate patient-reported knee function.

Objectively Measured Knee Function.

Isometric quadriceps strength at 90 degrees of knee flexion was used to objectively assess knee function at 18 months after ACLR. Quadriceps strength was chosen because it is related to the development of early symptomatic knee OA[30] and worse patient-reported physical function after ACLR.[31] Isometric knee strength was assessed using an established protocol on an electromechanical dynamometer (Biodex System 4 Pro, Biodex Medical Systems, Shirley, NY). All participants performed a standardized warm-up that included five minutes of walking on a treadmill, followed by 10 body weight squats, 10 lunges bilaterally, and 10 jump squats. Next, individuals completed three warm-up trials at 50%, 75%, and 100% maximal effort, followed by three, 5-second maximal trials with 60 seconds rest between each trial. Testing was completed in the uninjured limb followed by the injured limb. Participants were instructed to kick out against the shin pad "as hard and fast as possible," with verbal encouragement provided by the tester throughout the length of each effort. Quadriceps strength in the injured limb was compared to the uninjured limb using a limb symmetry index (LSI) ([involved/uninvolved] x 100%). The most commonly recommended criterion for isometric quadriceps strength limb symmetry after ACLR is 90%.[32] Therefore, 90% was set as the threshold for adequate quadriceps strength. Individuals with quadriceps strength less than 90% were identified as having inadequate quadriceps strength, while those at or above 90% were considered to have adequate quadriceps strength.

Based on patient-reported (IKDC) and objectively assessed (quadriceps strength) knee function, participants were classified into one of two categories. Participants with an IKDC score and isometric quadriceps strength ≥90% were categorized as having adequate knee function. Participants with an IKDC score or quadriceps strength less than 90% (either one or both) were categorized as having inadequate knee function.

Statistical Analysis

Means, standard deviations and 95% confidence intervals were calculated for continuous data. Frequencies and proportions were calculated for categorical data. Data from six and 18 months after ACLR were used to summarize individual patterns of sedentary behavior over time. A multilevel (two timepoints – six and 18 months), multidimensional (13 hours) functional principal components analysis was used. This provides two sets of unique personalized principal components scores: between participant (person-level principal components, PPC) and within-participant (follow-up level principal components, FPC). A principal component analysis approach allows for the summarization of variations in the amount of time spent in SB, represented by 13 variables, one for each hour into a reduced number of variables, known as Principal Components (PCs), while retaining most of the important information.[33] The PCs are then rank ordered, with the first PC being the PC that describes the most variance between time in SB throughout the day within the data set. The second PC describes the second most variance, and so forth. Loadings are calculated for each hour based on how much that individual hour contributes to each individual PC. Each PC represents the pattern of SB and can be interpreted in terms of hourly behavior using loadings. Large loading indicates that a particular hour has a strong relationship to the corresponding PC. The sign of loading indicates whether a corresponding hour and a PC are positively or negatively associated. PCs that generate a cumulative sum of explained variance of approximately 90% were marked as SB patterns and used for clinical interpretation and downstream exploratory analysis. As functional principal component analyses are exploratory, a power estimate could not be performed.

Exploratory analysis.

An exploratory analysis was used to assess the relationship between SB patterns and structural and symptomatic signs related to knee OA. Scatterplots were created to visualize the relationship between PCs and change in T2 relaxation time. Box and whisker plots were created to visualize the relationship between PCs and symptoms of related to knee OA. While this visual inspection approach does not allow identification of statistical significance, this exploratory analysis does facilitate hypothesis generation for future studies.

Results

Of the 29 individuals from the initial cohort eligible for 18-month follow-up, 18 had complete data for analysis (Table 1). Participants were mostly female (83.3%) with a mean age of 19.7 years and mean BMI of 23.9 kg/m^2. Half of all participants had a meniscus repair, and the mean percentage of time in SB at 6 and 18 months after ACLR was 65.4% and 65.7%, respectively.

Table 1. Participant demographic and clinical information (N = 18).

	Frequency or Mean (SD)
Female:Male	15:3
Age (years)	19.7 (5.6)
BMI (kg/m^2)	23.9 (3.7)
Meniscus repair status (Yes:No)	9:9
Graft type (HS:PT:QT)	2:12:4
Percentage of time in sedentary behavior at 6 months after ACLR	65.4 (7.5)
Percentage of time in sedentary behavior at 18 months after ACLR	65.7 (9.0)

Abbreviations: SD: Standard deviation; CI: confidence interval; kg: kilograms; m: meter; HS: Hamstring; PT: Patellar tendon; QT: Quadriceps tendon; ACLR: anterior cruciate ligament reconstruction

Overall Sedentary Behavior at 6 and 18 Months after ACLR

The first four PPCs explain 92% of the participant level variation in SB across both six and 18 months after ACLR. The loadings for the first four PPCs are displayed in Figure 2. The sign of the loading indicates whether a corresponding hour and a PPC are positively or negatively associated with the sample mean. For example, in PPC1, 9:00 am was associated with more time in SB compared to the *sample* mean, whereas in PPC2, 9:00 am was associated with less time in SB compared to the *sample* mean. Participants with positive PPC1 (“*most time in SB*”) spent consistently more time in SB compared to the *sample* average. Participants with positive PPC2 (*"increased midday and early evening SB with decreased late evening SB")* were less sedentary in the late evening but had more sedentary time at midday and in the early evening. Participants with positive PPC3 (*"increased morning SB and decreased late afternoon SB"*) had increased SB in the morning and less time in SB in the late afternoon. Participants with positive PPC4 (*"spread out SB"*) demonstrated multiple periods of SB throughout the day.

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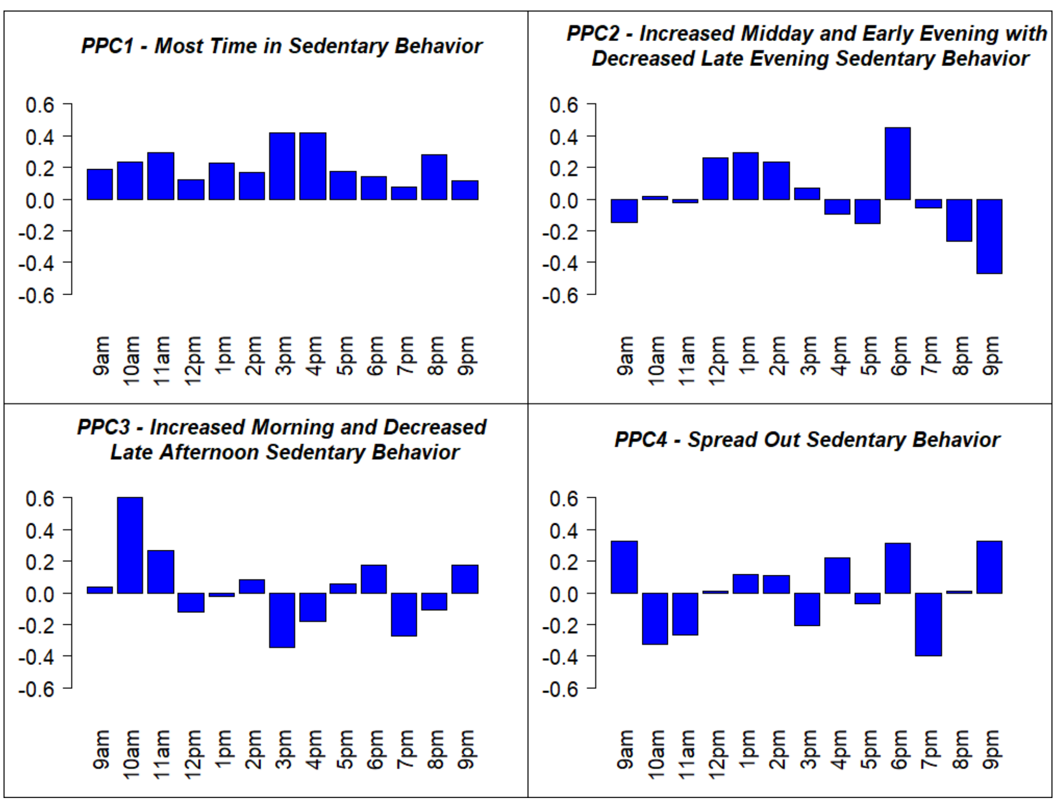

Figure 2. Participant-level principal components (PPCs) for the first four PPCs. Values to the above the x-axis (>0) indicate an increase in sedentary behavior compared to the sample mean at that hour, whereas values below the x-axis (<0) indicate a decrease in sedentary behavior compared to the sample mean at that hour. Abbreviations: SB: sedentary behavior

Visual inspection of the scatter plots (Appendix 1) demonstrated no relationship between SB pattern types and cartilage T2 relaxation times. Visual inspection of box and whisker plots for each PPC (Appendix 2) demonstrated no relationship between SB pattern type and knee function.

Changes in Sedentary Behavior from 6 to 18 Months after ACLR

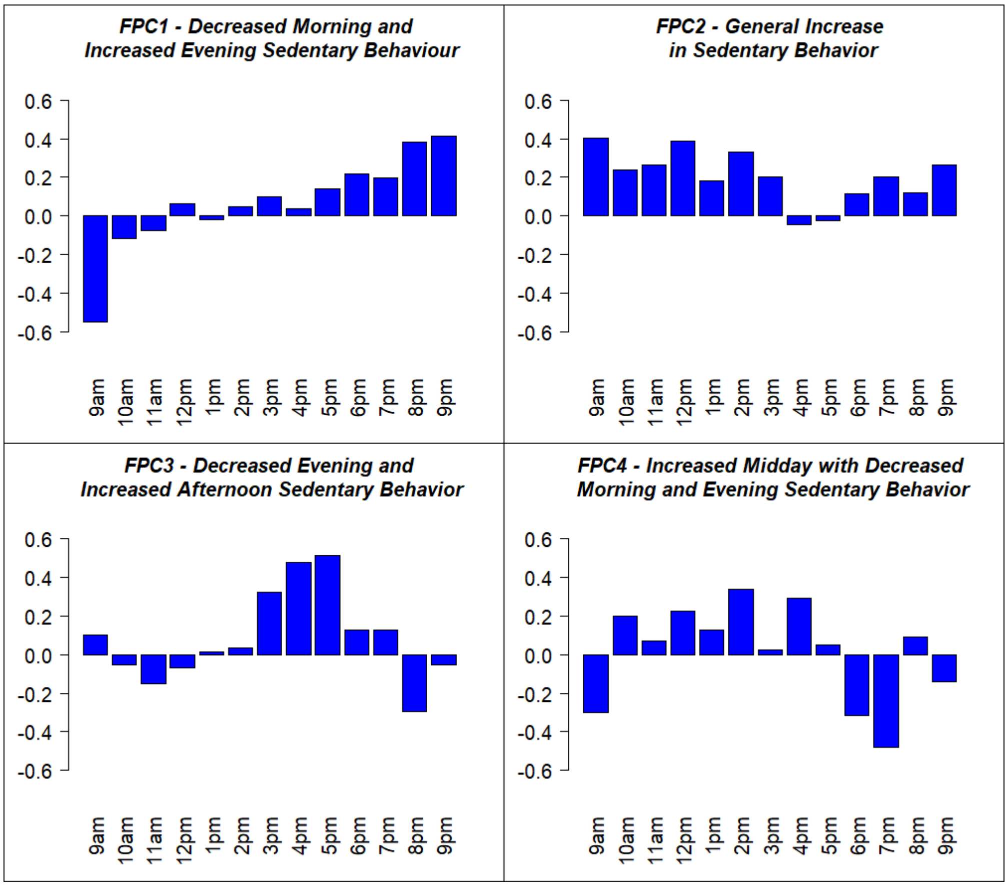

Figure 3. Follow-up-level principal components (FPCs) for the first four FPCs. Values above the x-axis (>0) indicate an increase in sedentary behavior at 18 months compared to the sample mean at 6 months, *whereas* values below the x-axis (<0) indicate a decrease in sedentary behavior at 18 months compared to the sample mean at 6 months. Abbreviations: SB: sedentary behavior

Follow-up level FPCs are time-specific functional deviations from *participant's* specific overall function, meaning that these FPCs detect a within-person shift in PA patterns. The average correlation between 2 days from the same person (the proportion of variability explained by person level functional clustering) was 30%. The first four FPCs explain almost 80% of the within-participant variance (Figure 3). As before, a positive loading for a particular hour indicates an increase in sedentary time from six to 18 months after ACLR, while a negative loading indicates a decrease in sedentary time. For example, individuals with a positive FPC1 ("*decreased morning and increased evening sedentary behavior*") had a decrease in sedentary time at 9:00 am from six to 18 months after ACLR, whereas individuals with a positive FPC2 ("*general* *increase in sedentary behavior"*) had an increase in sedentary time at 9:00 am from six to 18 months after ACLR. Participants with a positive FPC1 (*"decreased morning and increased evening sedentary behavior"*) at 18 months after ACLR demonstrated a decrease in morning sedentary time but an increase in evening sedentary time. Participants with a positive FPC2 (*"general increase in sedentary behavior"*) demonstrated increased sedentary time during almost all hours. Participants with a positive FPC3 (*"decreased evening and increased afternoon sedentary behavior"*) had decreased sedentary time in the late evening but increased sedentary time in the late afternoon (3:00 pm-5:00 pm). Participants with a positive FPC4 (*increased midday with decreased morning and evening sedentary behavior*) decreased their sedentary time in the morning (9:00 am) and evening (6:00 pm and 7:00 pm) but had increased sedentary time from 10:00 am-5:00 pm.

Visual inspection of the scatter plots (Appendix 3) demonstrated no relationship between changes in sedentary time and percent change cartilage T2 relaxation times from six to 18 months after ACLR. Visual inspection of box and whisker plots (Figure 4) for each FPC demonstrated a positive relationship between FPC1 and knee function at 18 months after ACLR. This is evident by the minimal overlap of the FPC loading values between the adequate and inadequate knee function groups.

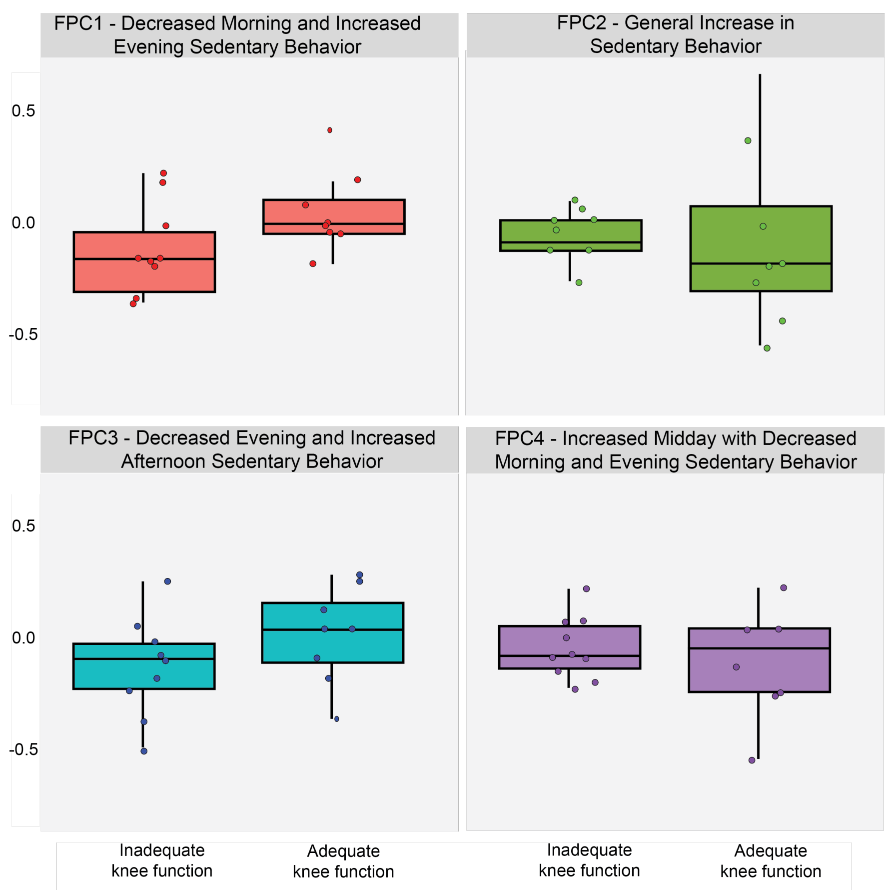

Figure 4. Box and whisker plots of the mean correlation with each participant level principal component separated by knee function group. Adequate knee function = >90% quadriceps strength symmetry and >90% on the International Knee Documentation Committee form

Discussion

This study suggested four distinct SB patterns at six and 18 months after ACLR (PPC1-4, Figure 2). Relationships were not found between SB patterns at six and 18 months after ACLR with either structural or symptomatic signs of early onset knee OA. There were also four patterns of distinct SB pattern changes present from six to 18 months (FPC1-4, Figure 3). There was a relationship between SB and knee function, as the adequate knee function group positively correlated with FPC1 (decreased in morning sedentary time at 18 months after ACLR compared to 6 months).

To our knowledge, this is the first study to investigate SB patterns throughout the day in individuals after ACLR. Most of the individuals in the current study were school-aged (61.1% in high school; 22.2% in college). Previous studies have quantified SB in uninjured members of this age group. These previous studies report greater levels of SB in adolescents and school-aged individuals (up to 83.2%)[34-38] compared to our study (65.6%), although one study reported a lower percentage of time spent by adolescents in SB (35%).[38] Fifteen of the 18 individuals in the current cohort were school-aged, most of which were high school students. Those who were high school students spent 66.3 ± 9.1% of the time in SB, while those who were college students spent 61.5 ± 4.3% of the time in SB. This follows the patterns of previous studies that show that amount of time in SB increases from early adolescence to high school and then decreases during college years.[37,39] The reduced time in SB noted in the current study compared to previous reports may be related to the activity level of the participants in the current study. All the school-aged participants in the current study participated in competitive or recreational sports. Their previous experience with sports may signify that they are more likely to be self-motivated to be participants in sport activities and PA in general. An increase in self-motivation in the current cohort would align with the results of Mayorga-Vega and colleagues,[36] who reported that individuals who had self-determination regarding PA spent less time in sedentary behavior.

Participants in this current study had a similar average percentage of time in SB (65.5 ± 8.2%) compared to older individuals at risk or currently with hip and knee OA (57-73%).[22,40] The current cohort of mostly school-aged individuals likely had different daily schedule demands than the older individuals from previous studies. For example, the individuals in the current cohort may have had a less flexible schedule during the day due to school demands. However, they may have had activities before, during, and after school that promote PA. Future interventions aiming to reduce time spent in sedentary behavior in school-aged individuals after ACLR may need to identify times during the day that provide the opportunity and flexibility to allow for PA to interrupt sedentary time.

Understanding the amount of time spent in SB provides insight into how much time is spent in general PA, as a reduction in time spent in SB can imply an increase in time spent in general PA. An increase in general weightbearing PA would infer an increase in knee joint loading. Knee joint loading is important for articular cartilage health because cartilage requires cyclic dynamic physiologic loading to promote extracellular matrix synthesis.[41] Additionally, a lack of loading results in a softening of the cartilage and an alteration in the ability of the cartilage to tolerate load.[41] While the current study did not identify a relationship between changing SB and structural signs of cartilage health in the current study, this may speak to the role of cumulative loading and structural health. A study from the Osteoarthritis Initiative (OAI, N = 1091) showed that individuals who were physically inactive, as measured by accelerometry, have up to a 72% increased risk of developing functional limitations related to OA.[12] In another large cohort study of 1,788 participants from the Multicenter Osteoarthritis Study (MOST), every 1000 step/day increase in PA was associated with a 16-18% reduced risk of functional limitations over a 2-year period.[13] Additionally, interventions that successfully increase total PA in those with OA also improve their physical function and quality of life[14] and are recommended by several rheumatological organizations, such as the American College of Rheumatology,[42] and the Arthritis Foundation.[42] In the current study, a shift in reducing SB in the morning (FPC1) appeared to have a positive correlation with adequate knee function, whereas the other patterns that included smaller shifts towards less sedentary time were not associated with adequate knee function. As there is a potential for structural changes to occur with reduced knee joint loading related to increased SB, a relationship between reduced morning SB and adequate knee function by 18 months may be linked to improved structural signs and symptoms related to knee OA. Therefore, it may be more important to limit overall SB throughout the day. Interventions may be most helpful if they individually target specific hours of the day in which a patient is most able to reduce SB.

The small sample size in this study limits the generalizability of the results, may have affected our ability to detect differences in knee health outcomes between SB pattern types, and may have impacted the exploratory analysis as the results of one participant may influence the spread of data. Additionally, only three male participants completed 18-month follow up data collections compared to 15 female participants. This limits the generalizability beyond female individuals, as multiple larger survey studies have found that worldwide, female individuals spend more time in SB and have lower levels of PA than male individuals.[43] There were no additional demographic differences (age, concomitant involvement, sport participation) between the 18 individuals included in this study and the 11 individuals who did not complete full follow-up at the 18-month timepoint. As mentioned previously, a decrease in SB is helpful in identifying when overall PA may be increasing. However, we did not analyze the intensity of the activities that the participants were performing in this analysis.

In conclusion, different patterns of SB were present in individuals at six and 18 months after ACLR. By identifying the time of day that individuals were most likely to be participating in SB, clinicians can target specific times for increasing PA. Additionally, reducing morning time SB from six to 18 months after ACLR was associated with having adequate knee function. While a causative effect cannot be determined, clinicians should assist patients in identifying strategies to reduce and/or break up their SB by increasing their PA throughout their recovery from ACLR.

Acknowledgements

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Appendix 1

Visual inspection of scatter plots demonstrated no relationship between person-level principal components (PPCs) and structural or symptomatic assessments of knee health. The following figures regarding the scatterplots follow the same organization. The figures are separated into three rows to display the relationship between each of the top three PPCs and the percent change in T2 relaxation time. Additionally, the top right, middle, and bottom right graphs display a kernel density curve with each dot representing an individual. The shade of the dot represents the strength and direction of the percent change in T2 relaxation time. If all dots of a specific shade were clustered, it would indicate a likely relationship with the pattern type and percent change in T2 relaxation time. For the six remaining scatterplots, a cluster of individuals with similarly shaded dots signifies a likely presence of a relationship between the patterns and percent change in T2 relaxation time. For instance, if there were two noticeable groups of dots – one group of dark dots clustered in the top left of a graph and one group of light gray dots clustered in the top right, it would be likely that the two patterns have different relationships with T2 relaxation time.

Lateral Femoral Cartilage

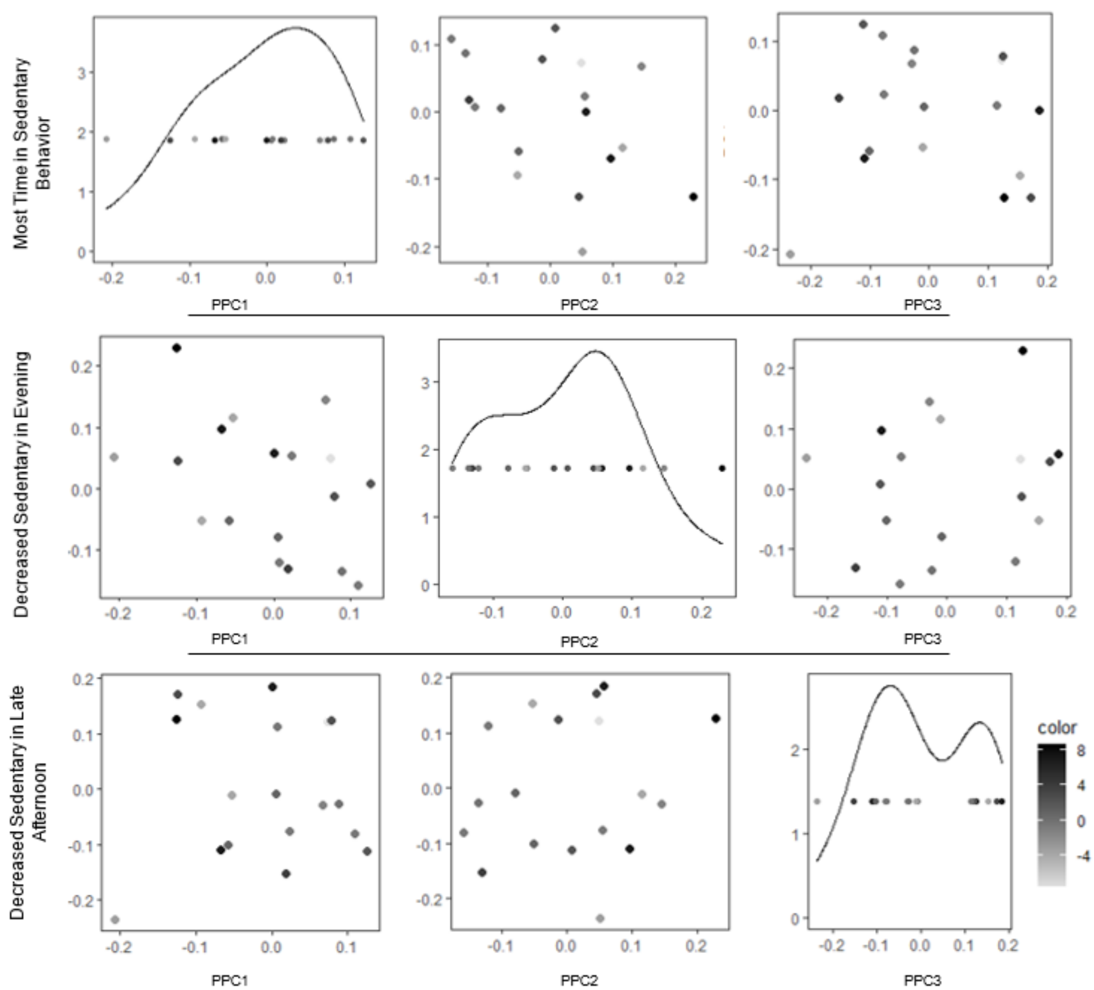

Figure Appendix 1a. Participant-Level Principal Components and Lateral Femoral Cartilage T2 Relaxation Time

Graphical depiction of participant-level components (PPCs). The x- and y-axis values are the associated PPC values for each participant. The shade of the dot represents the strength and direction of the percent change of T2 relaxation time for the lateral femoral cartilage.

Lateral Tibial Cartilage

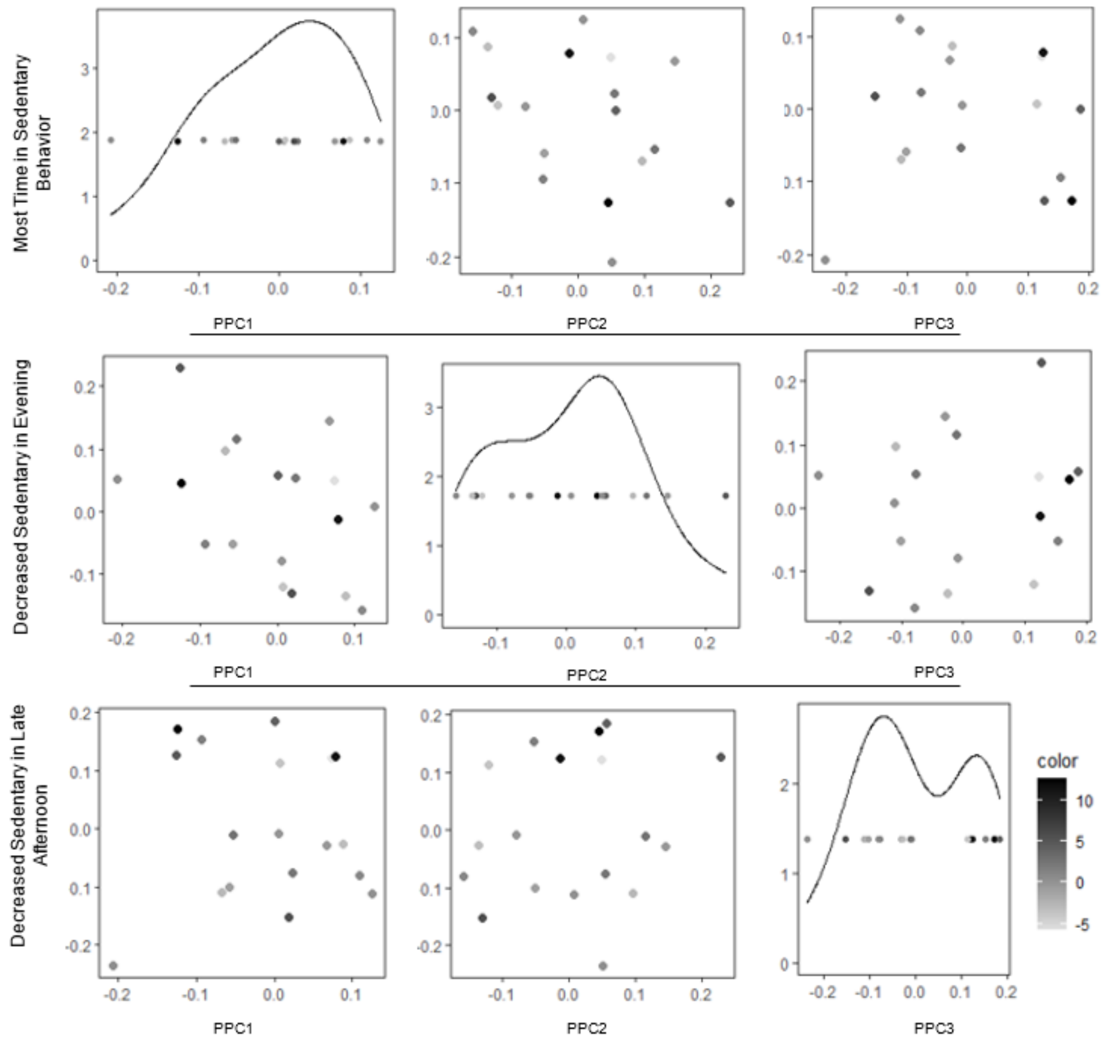

Figure Appendix 1b. Participant-Level Principal Components and Lateral Tibial Cartilage T2 Relaxation Time Graphical depiction of participant-level components (PPCs). The x- and y-axis values are the associated PPC values for each participant. The shade of the dot represents the strength and direction of the percent change of T2 relaxation time for the lateral tibial cartilage.

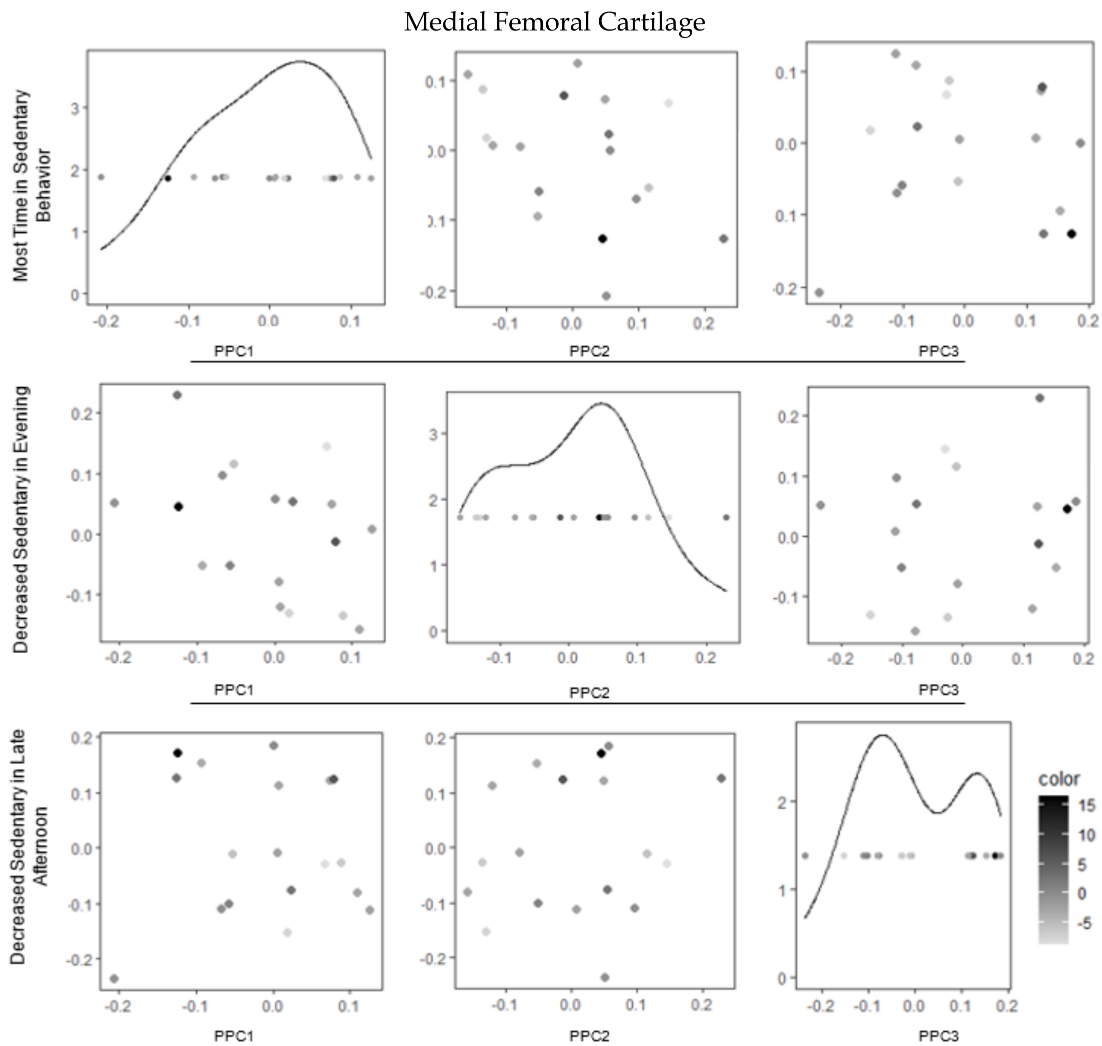

Figure Appendix 1c. Participant-Level Principal Components and Medial Femoral Cartilage T2 Relaxation Time

Graphical depiction of participant-level components (PPCs). The x- and y-axis values are the associated PPC values for each participant. The shade of the dot represents the strength and direction of the percent change of T2 relaxation time for the medial femoral cartilage.

Appendix 2

For the box and whisker plots, a noticeable difference in the median correlation between the knee function groups would indicate that there likely was a relationship between the group allocation and the sedentary behavior pattern.

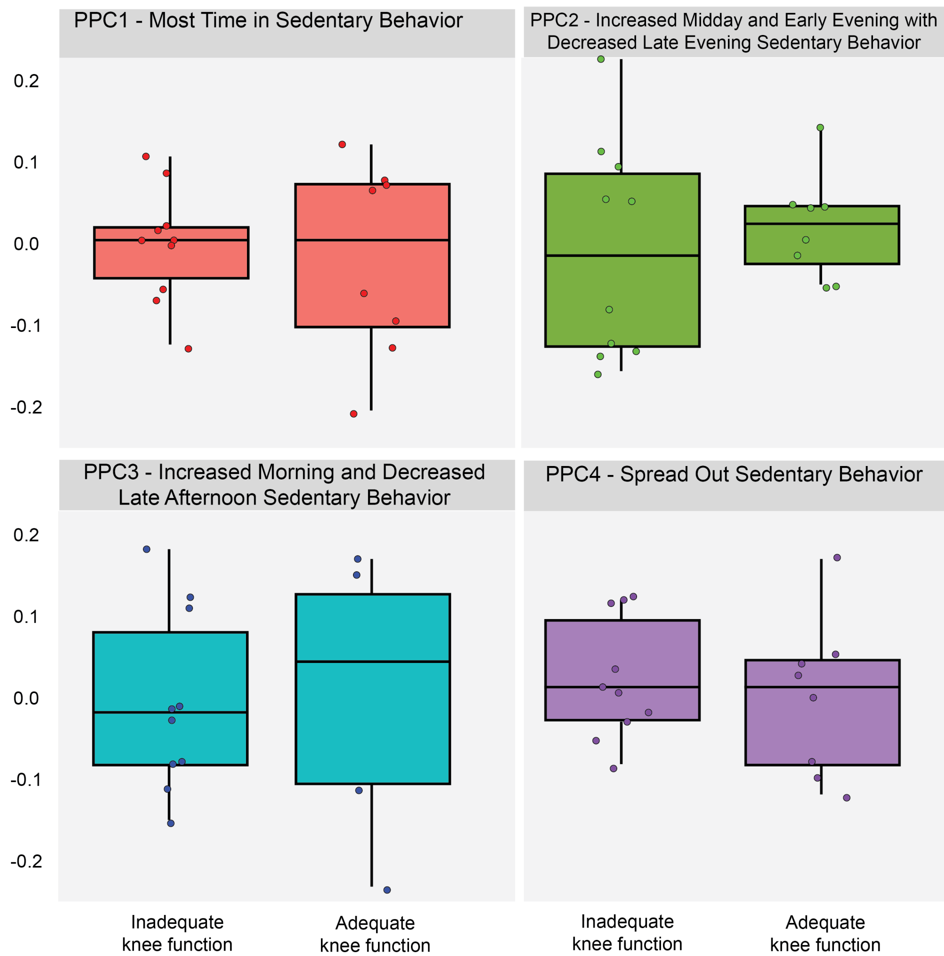

Figure Appendix 2. Box and whisker plots of the mean correlation with each participant level principal component separated by knee function group.

Appendix 3

The following figures are separated into three rows to display the relationship between each of the top three FPCs and the percent change in T2 relaxation time. Additionally, the top right, middle, and bottom right graphs display a kernel density curve with each dot representing an individual. The shade of the dot represents the strength and direction of the percent change in T2 relaxation time. If all dots of a specific shade were clustered, it would indicate a likely relationship with the pattern type and percent change in T2 relaxation time. For the six remaining scatterplots, a cluster of individuals with similar shades of dots signifies a likely presence of a relationship between the patterns and percent change in T2 relaxation time. For instance, if there were two noticeable groups of dots – one group of dark dots clustered in the top left of a graph and one group of light gray dots clustered in the top right, it would be likely that the two patterns have different relationships with T2 relaxation time.

Lateral Femoral Cartilage

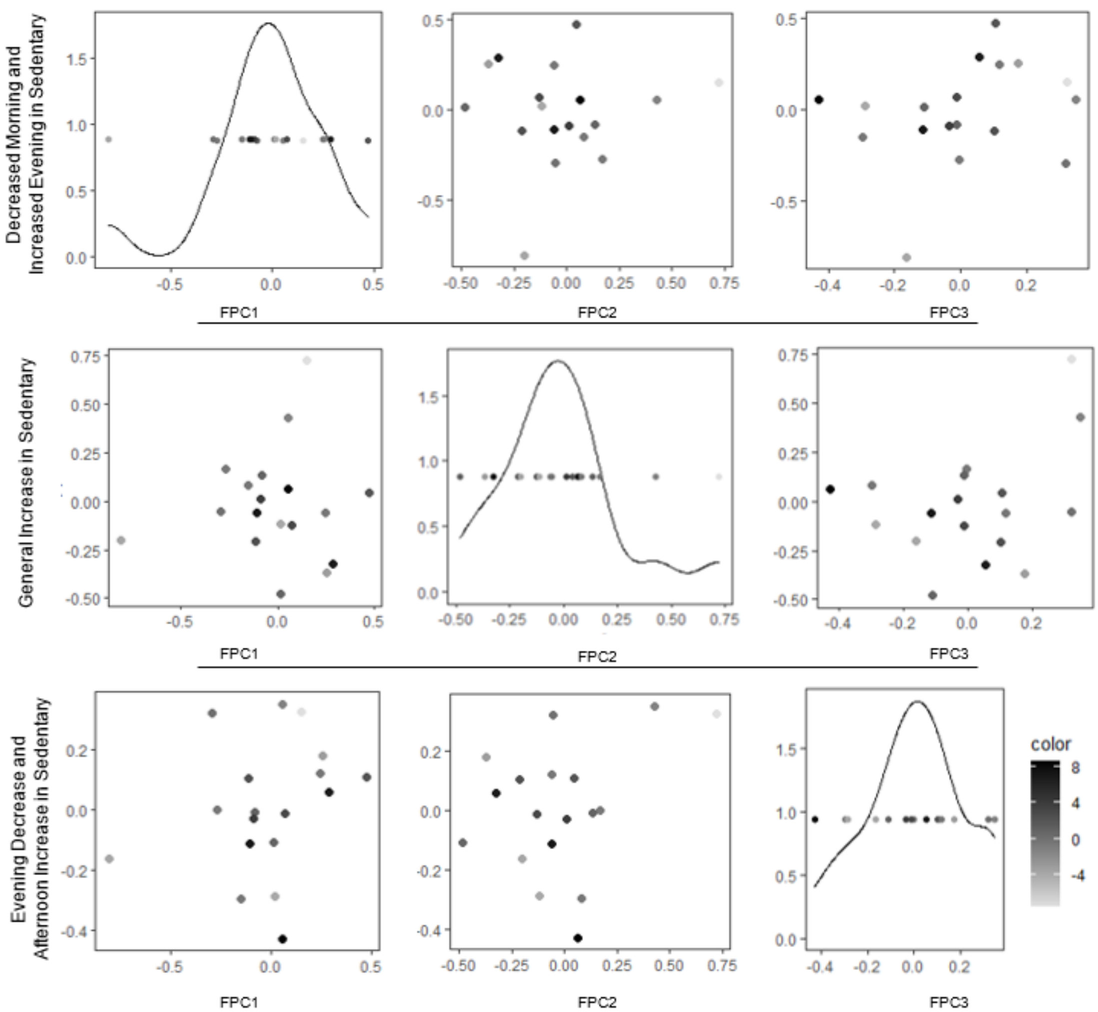

Figure Appendix 3a. Follow-up Level Principal Components and Lateral Femoral Cartilage T2 Relaxation Time

Graphical depiction of follow-up level components (FPCs). The x- and y-axis values are the associated FPC values for each participant. The shade of the dot represents the strength and direction of the percent change of T2 relaxation time for the lateral femoral cartilage.

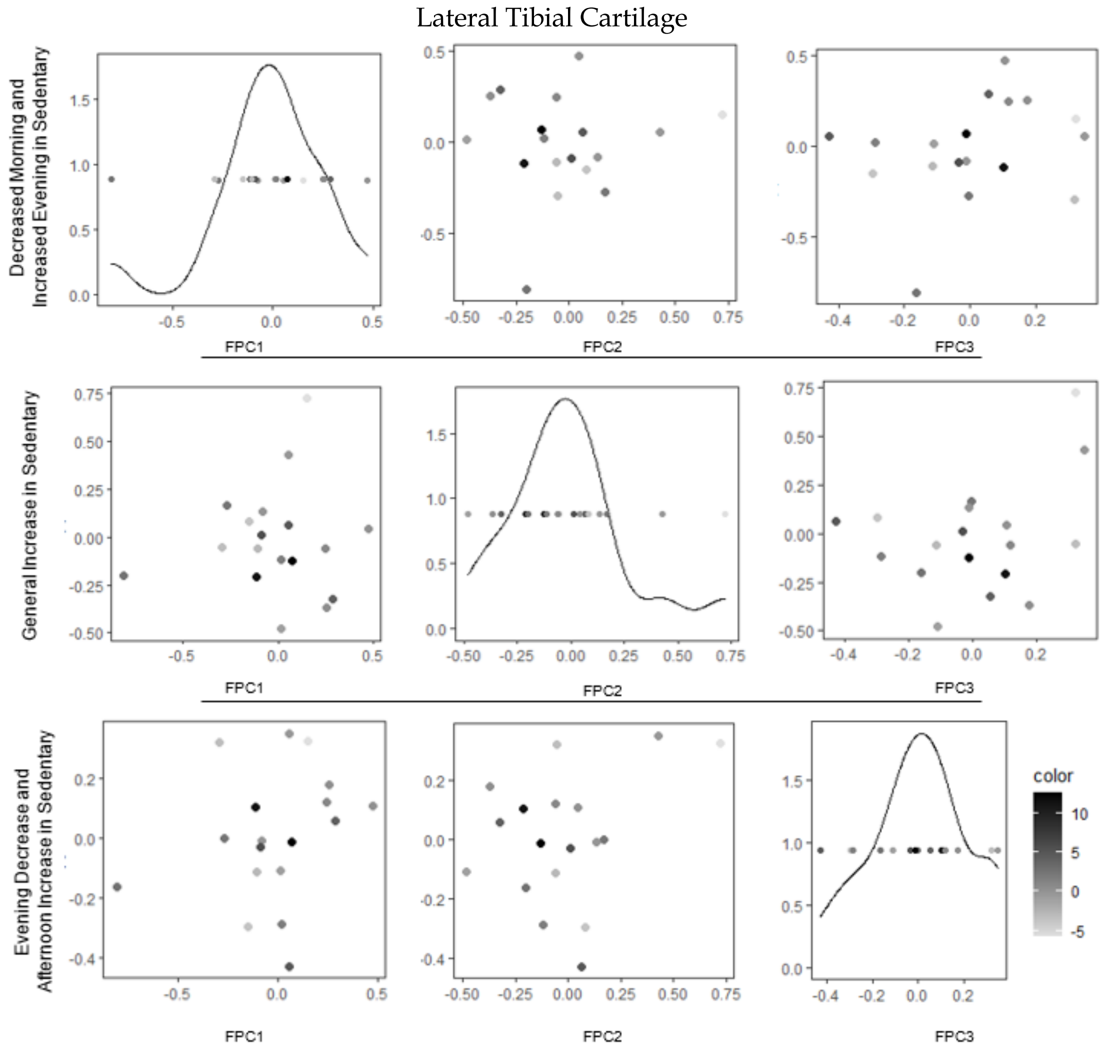

Figure Appendix 3b. Follow-up Level Principal Components and Lateral Tibial Cartilage T2 Relaxation Time
Graphical depiction of follow-up level components (FPCs). The x- and y-axis values are the associated FPC values for each participant. The shade of the dot represents the strength and direction of the percent change of T2 relaxation time for the lateral tibial cartilage.

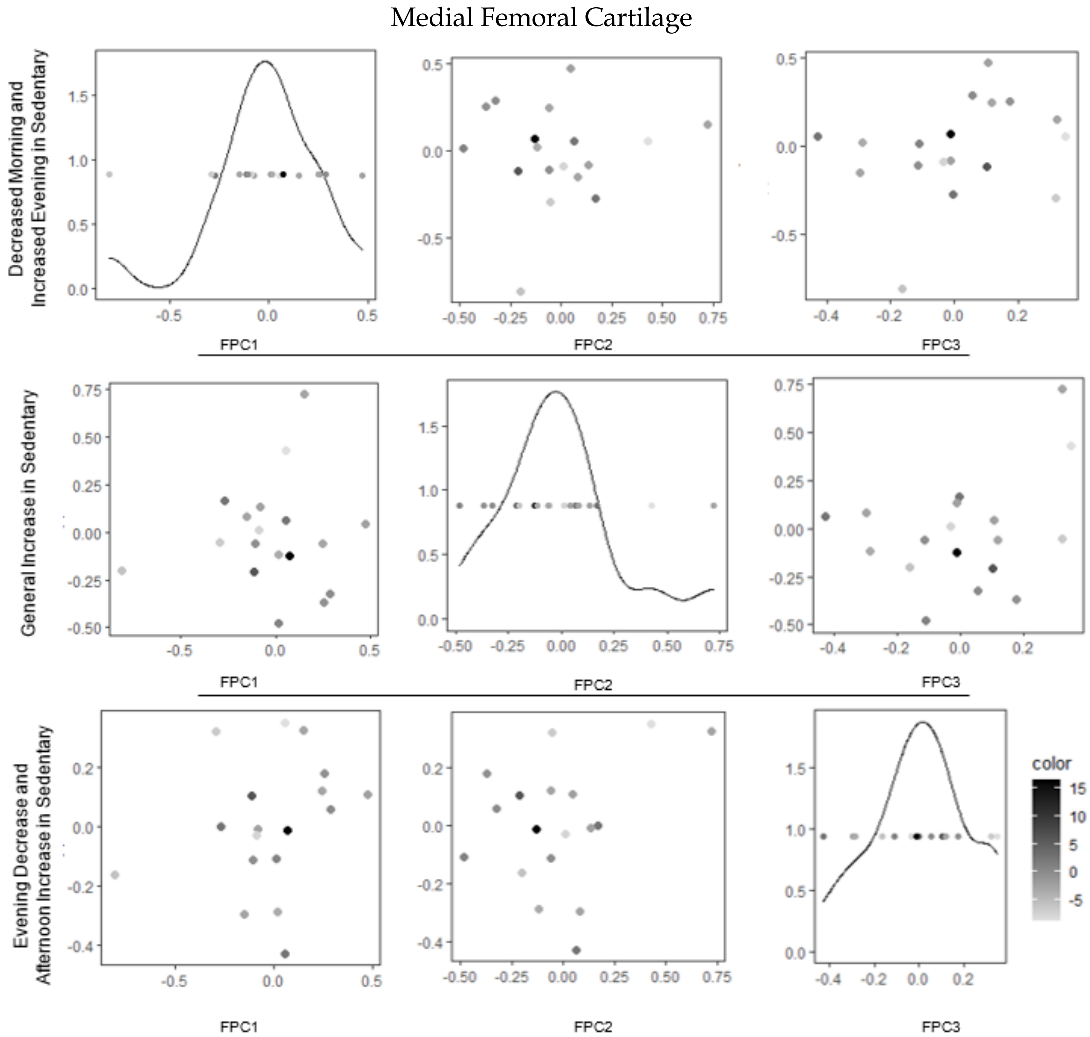

Figure Appendix 3c. Follow-up Level Principal Components and Medial Femoral Cartilage T2 Relaxation Time
Graphical depiction of follow-up level components (FPCs). The x- and y-axis values are the associated FPC values for each participant. The shade of the dot represents the strength and direction of the percent change of T2 relaxation time for the medial femoral cartilage.