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Association of Quality of Life With Moderate-to-Vigorous Physical Activity After Anterior Cruciate Ligament Reconstruction

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Context: Better knee function is linked to psychological readiness to return to sport after anterior cruciate ligament reconstruction (ACLR). Individuals with ACLR participate in less physical activity than matched uninjured control individuals, yet the association between knee function and physical activity post–ACLR remains unclear.

Objective: To determine the associations between (1) patient-reported knee function measured using the Knee Injury and Osteoarthritis Outcome Score Knee-Related Quality of Life (KOOS-QOL), daily steps, and minutes spent in moderate-to-vigorous physical activity (MVPA) of individuals with ACLR and (2) KOOS-QOL and daily steps and MVPA in individuals with ACLR who presented with (ie, symptomatic) or without (ie, asymptomatic) clinically meaningful knee-related symptoms.

Design: Cross-sectional study.

Setting: Laboratory, free-living conditions.

Patients or Other Participants: A total of 66 individuals with primary unilateral ACLR (36 women, 30 men; age = 22 ± 4 years, height = 1.71 ± 0.1 m, mass = 71.3 ± 12.6 kg, body mass index = 24.2 ± 2.9, time post–ACLR = 28 ± 33 months).

Main Outcome Measure(s): We collected KOOS data and retrospectively stratified participants into those with (symptomatic group, n = 30) or without (asymptomatic group, n = 36) clinically meaningful knee-related symptoms based on previously defined KOOS cutoffs. We assessed daily steps and MVPA using accelerometers that participants wore on the right hip for 7 days. We conducted linear regressions to determine associations between KOOS-QOL and daily steps and MVPA.

Results: In the entire sample, no associations existed between KOOS-QOL and daily steps ($\Delta R^2 = 0.01$, $P = .50$) or MVPA ($\Delta R^2 = 0.01$, $P = .36$). In the symptomatic group, a greater KOOS-QOL was associated with more time in MVPA ($\Delta R^2 = 0.12$, $P = .05$). In the asymptomatic group, no associations were identified between the KOOS-QOL and daily steps and MVPA.

Conclusions: Individuals with symptoms post–ACLR who spent more time in MVPA reported higher QOL.

Key Words: daily steps, physical activity, Knee Injury and Osteoarthritis Outcome Score, patient-reported outcomes

Key Points

- Individuals with symptoms post–anterior cruciate ligament reconstruction who spent more time engaged in moderate-to-vigorous physical activity reported better knee-related quality of life.
- No association existed between physical activity and quality of life in either the entire cohort or the asymptomatic group post–anterior cruciate ligament reconstruction.

Anterior cruciate ligament (ACL) injury is a common traumatic musculoskeletal injury sustained by young, physically active adults.[1] Approximately 43% of individuals reported clinically meaningful knee symptoms measured using the Knee Injury and Osteoarthritis Outcome Score (KOOS) at 2 years post–ACL injury, and 39% of individuals reported symptoms 6 years post–ACL injury, despite undergoing ACL reconstruction (ACLR) and rehabilitation to reestablish joint stability and function.[2] It is critical to determine the factors associated with persistent deficits in knee function in order to develop the novel interventions needed to improve long-term knee function post–ACLR. Approximately 82% of individuals returned to some level of sport participation post–ACLR,[3] yet between 43% and 63%[4] of patients did not return to preinjury levels of sport, which may reflect less overall physical activity (PA) participation.[4] A reduction in PA may be linked to the development

of poor knee function, yet few data exist to identify the association between PA and knee function in individuals post–ACLR. Whether clinically meaningful knee symptoms are linked to PA in individuals post–ACLR is unknown.

Physical activity is important for overall well-being and is associated with higher general quality of life (QOL) in children and older adults.[5,6] Greater PA was associated with reduced mortality[7] and fewer chronic diseases, including coronary heart disease and type 2 diabetes.[8] However, whether PA is associated with knee-related QOL post–ACLR is unclear. Individuals with lower extremity musculoskeletal injuries often demonstrate reductions in PA,[9,10] and preliminary evidence has suggested that those with ACLR engaged in less PA than healthy control individuals.[11] In a cross-sectional study, researchers[11] measured PA using hip-mounted accelerometers and found that individuals who were 6 to 67 months post–ACLR engaged in fewer daily steps and spent less time in moderate-to-vigorous PA (MVPA) than uninjured control individuals matched for age, sex, and sport participation (via Tegner score). Lower knee-related QOL was associated with lower levels of PA in individuals with knee osteoarthritis (KOA), and interventions to increase PA were successful in improving patient-reported outcomes in those with KOA.[12–14] Promotion of customized PA is not a standard component of traditional ACLR rehabilitation, suggesting that reengaging in PA is often left to the discretion of the patient. If inadequate PA is linked to a poor KOOS, PA promotion may be used to improve knee-function QOL. Determining the association between PA and knee-function QOL is important for developing a rationale for targeting PA during and after ACLR rehabilitation.

The primary aim of our study was to examine the association between knee-function QOL, measured using the KOOS, and objectively measured daily steps and time spent in MVPA in individuals post–ACLR. We hypothesized that more daily steps and MVPA would be associated with better KOOS outcomes. As noted, clinically meaningful symptoms may persist in approximately 40% of individuals post–ACLR,[4] and these symptoms may affect engagement in PA post–ACLR. Individuals experiencing symptoms of knee pain or stiffness post–ACLR may demonstrate a different relationship between PA and KOOS-QOL than asymptomatic individuals who do not need to consider pain or stiffness when engaging in PA. Therefore, our secondary purpose was to investigate associations between the KOOS and daily steps and time spent in MVPA of individuals with ACLR who presented with (ie, symptomatic) or without (ie, asymptomatic) clinically meaningful knee-related symptoms.[15,16] We hypothesized that individuals with symptoms would demonstrate stronger associations between more daily steps, more MVPA, and better KOOS outcomes post–ACLR.

METHODS

Design

For this cross-sectional study, we recruited potential participants via orthopaedic surgeons in the University Health System of the University of North Carolina at Chapel Hill, flyers placed at outpatient physical therapy clinics and club soccer fields, and university classes. We assessed descriptive variables and the KOOS in participants during a single visit to the laboratory. We measured their daily steps and time in MVPA using an ActiGraph GT9X Link triaxial accelerometer (ActiGraph, LLC) worn for 7 consecutive days after the laboratory visit. The institutional review board at the University of North Carolina at Chapel Hill approved the study, and all participants provided written informed consent.

Participants and Power Analysis

Individuals who had undergone unilateral ACLR at least 6 months before data collection, had physician approval to return to unrestricted participation in PA, were between the ages of 18 and 35 years, and had a body mass index $\leq$35 were eligible for the study. We excluded individuals who were pregnant, had been diagnosed with any form of inflammatory arthritis, needed a multiligament reconstruction, or had a history of ACLR of the involved or contralateral limb. Descriptive data and self-reported concomitant meniscal injury information are shown in Tables 1 and 2. Previous researchers[17] have demonstrated an association (odds ratio = 0.41; 95% CI = 0.26, 0.63) between less self-reported sport-related activity using the Marx Activity Rating Scale and a lower KOOS in an ACLR cohort. Using G*Power (version 3.1.9.2),[18] we determined, based on the effect size (Hedges $g = -0.21$) from an earlier investigation,[17] that 66 participants would be needed to detect a moderate association ($R^2 = 0.15$) between the KOOS and daily steps and MVPA ($\alpha = .05$, 80% power).

Knee Injury and Osteoarthritis Outcomes Score

Participants completed the 5 subscales of the KOOS (Pain, Symptoms, Activities of Daily Living [ADL], Sport and Recreation Function [Sports], and Knee-Related Quality of Life [QOL]) via a health care informatics system (REDCap; Vanderbilt University). The KOOS is a valid and reliable assessment of functional status and QOL in individuals post–ACLR.[19,20] The KOOS subscale scores range from 0–100, with 100 representing the *best possible score*.

We used a definition developed by Englund et al[15] in an ACLR cohort to dichotomize participants into those with (symptomatic) or those without (asymptomatic) clinically meaningful knee-related symptoms. Individuals reporting a KOOS-QOL $\leq$ 87.5 as well as $\geq$2 of the other 4 subscores below the cutoff values (KOOS Symptoms $\leq$ 85.7, KOOS Pain $\leq$ 86.1, KOOS-ADL $\leq$ 86.8, KOOS Sports $\leq$ 85.0) were considered symptomatic.[15] We chose the KOOS-QOL subscore as our primary outcome because we were most interested in how overall knee-related QOL was influenced by PA, and KOOS-QOL was the most responsive subscore.[21–23]

Physical Activity Measured Using Hip-Mounted Accelerometers

Participants wore an ActiGraph GT9X Link triaxial accelerometer over the right anterior-superior iliac spine during waking hours for 7 consecutive days immediately after the study visit. The ActiGraph GT9X Link is a valid device for quantifying PA in free-living conditions.[24] We considered a data-collection period acceptable if it included $\geq$4 days (3 weekdays and 1 weekend day) of wear for $\geq$10

Table 1. Descriptive Variables, Knee Injury and Osteoarthritis Outcome Scores, Daily Steps, and Moderate-to-Vigorous Physical Activity in Asymptomatic and Symptomatic Groups After Anterior Cruciate Ligament Reconstruction

Variable	Entire Sample (N = 66)	Asymptomatic Group (n = 36)	Symptomatic Group (n = 30)
Sex, No.			
Male	30	19	11
Female	36	17	19
Graft type, No.			
Bone-patellar tendon-bone	48	27	21
Semitendinosus autograft	14	8	6
Allograft	2	0	2
Quadriceps tendon autograft	2	1	1
Meniscal injury, No.			
Medial	15	9	6
Lateral	13	7	6
Both	3	1	2
No injury	29	14	15
Unknown	6	5	1
Characteristic, Entire Sample and mean ± SD			
Age, y	22 ± 4	22 ± 4	22 ± 5
Height, m	1.71 ± 0.1	1.71 ± 0.09	1.71 ± 0.09
Mass, kg	71.3 ± 12.6	71.2 ± 14.2	71.5 ± 10.5
Body mass index	24.2 ± 2.9	24.0 ± 2.9	24.4 ± 2.8
Time from anterior cruciate ligament reconstruction, mo	28 ± 33	39 ± 40	16 ± 15[b]
Knee Injury and Osteoarthritis Outcome Score subscale (1–100 scale)			
Symptoms	82.0 ± 13.7	90.3 ± 7.6	72.0 ± 12.9[a]
Pain	90.1 ± 7.8	95.3 ± 3.6	83.8 ± 6.8[a]
Activities of Daily Living	97.5 ± 3.9	99.3 ± 1.3	95.2 ± 4.2[a]
Sport and Recreation Function	79.2 ± 16.6	89.3 ± 9.3	67.2 ± 15.3[a]
Knee-Related Quality of Life	69.6 ± 19.0	81.8 ± 11.8	55.0 ± 15.4[a]
Daily steps, No.	8602 ± 2466	8881 ± 2584	8266 ± 2316
Moderate-to-vigorous physical activity, min/d	69 ± 26	72 ± 27	66 ± 25
ActiGraph[b] wear time, min/d			
Average daily	851 ± 69	840 ± 64	863 ± 73
Total	4967 ± 937	4895 ± 880	5074 ± 1007

[a] Different from asymptomatic group ($P < .05$).
[b] Model GT9X Link triaxial accelerometer (ActiGraph, LLC).

hours per day.[25] Participants removed their monitors for bathing and sleeping. They returned their monitors after the wear period, at which time we assessed the data for fidelity and consistency with wear guidelines.[25] The accelerometer did not specifically account for non–weight-bearing activities such as swimming and bicycling.

We processed average daily steps and time in MVPA (minutes) using ActiLife software (version 6.13.3; ActiGraph, LLC). We evaluated total wear time using recommendations from Choi et al[25] (zero-count threshold during a nonwear time interval, 90-minute time window for consecutive zero or nonzero counts, and allowance of a 2-minute interval of nonzero counts with the upstream and downstream 30-minute consecutive zero-counts window for detection of artifactual movements) to ensure that each participant wore the ActiGraph for $\geq$4 days for $\geq$10 hours per day. We used Freedson Adult triaxial vector magnitudes cut points to calculate time in MVPA (2690–9642 counts/min).[26] Daily steps were assessed using vertical acceleration data measured using the ActiGraph monitor. We averaged variables over valid wear days to create a daily average.[11]

Statistical Analysis

Means and SDs were calculated for all continuous descriptive and outcome variables and frequencies for all noncontinuous variables. Before analysis, we identified outliers via box plots as any data points >3 times the interquartile range and removed them before our primary analyses. We conducted independent *t* tests for all descriptive and outcome variables between asymptomatic and symptomatic groups.

For our primary analyses, we performed separate multiple regressions with each PA variable (daily steps and MVPA) as a separate predictor variable and KOOS-QOL as the criterion variable. Age was associated with PA,[27] and time post–ACLR was associated with the KOOS.[17] Therefore, we included age and time post–ACLR as covariates in each regression before the KOOS. A history of concomitant meniscal injury may also be associated with KOOS outcomes post–ACLR. Concomitant meniscal injury was self-reported, and 6 participants selected *unknown* when asked about meniscal injury. Thus, we removed these 6 participants and conducted a sensitivity analysis evaluating the associations between the KOOS-QOL and PA variables with 3 covariates: age, time post–ACLR, and history of concomitant meniscal injury.

For our secondary analyses, we calculated separate multiple regressions between each PA variable and the KOOS-QOL as described for the primary aim in each group (ie, asymptomatic or symptomatic) with the inclusion of age and time post–ACLR as covariates. Similarly, we performed a sensitivity analysis to evaluate the associations between the KOOS-QOL and PA variables in each group (asymptomatic and symptomatic)

Table 2. Descriptive Variables, Daily Steps, Moderate-to-Vigorous Physical Activity, and Knee Injury and Osteoarthritis Outcome Scores in Asymptomatic and Symptomatic Men and Women After Anterior Cruciate Ligament Reconstruction

	Men		Women	
Variable	Asymptomatic (n = 19)	Symptomatic (n = 11)	Asymptomatic (n = 17)	Symptomatic (n = 19)
Graft type, No.				
Bone-patellar tendon-bone	13	8	14	13
Semitendinosus autograft	6	3	2	3
Allograft	0	0	0	2
Quadriceps tendon autograft	0	0	1	1
Meniscal injury, No.				
Medial	7	3	2	3
Lateral	3	2	4	4
Both	1	1	0	1
No injury	6	5	8	10
Unknown	2	0	3	1
Characteristic, mean ± SD				
Age, y	23 ± 4	23 ± 5	20 ± 2[a]	21 ± 4
Height, m	1.78 ± 0.07	1.80 ± 0.06	1.64 ± 0.05[a,b]	1.66 ± 0.07[a,b]
Mass, kg	80.3 ± 12.7	78.7 ± 9.6	61.0 ± 7.3[a,b]	67.3 ± 8.8[a,b]
Body mass index	25.2 ± 3.0	24.4 ± 2.2	22.7 ± 2.2	24.4 ± 3.2
Time from anterior cruciate ligament reconstruction, mo	51 ± 48	9 ± 4[a]	25 ± 22	19 ± 17[a]
Knee Injury and Osteoarthritis Outcome Score subscale (1–100 scale)				
Symptoms	91.9 ± 7.0	72.1 ± 10.8[a]	88.4 ± 7.9[b]	72.0 ± 14.2[a,c]
Pain	96.3 ± 3.1	86.4 ± 7.3[a]	94.1 ± 3.9[b]	82.3 ± 6.2[a,c]
Activities of Daily Living	99.5 ± 1.1	95.2 ± 3.9	98.7 ± 2.2	92.9 ± 8.0[a,c]
Sport and Recreation Function	89.5 ± 7.8	68.6 ± 11.2[a]	89.1 ± 10.9[b]	66.3 ± 17.5[a,c]
Knee-Related Quality of Life	85.2 ± 11.3	50.0 ± 16.1[a]	77.9 ± 11.5[b]	57.9 ± 14.7[a,c]
Daily steps, No.	8751 ± 2367	8194 ± 2004	9026 ± 2874	8308 ± 2531
Moderate-to-vigorous physical activity, min/d	76 ± 21	73 ± 19	67 ± 33	62 ± 28

[a] Different from asymptomatic men ($P < .05$).
[b] Different from symptomatic men ($P < .05$).
[c] Different from asymptomatic women ($P < .05$).

including 3 covariates: age, time post–ACLR, and history of concomitant meniscal injury. For the supplementary analyses, we conducted similar regressions for the other KOOS subscores (KOOS Symptoms, KOOS Pain, KOOS-ADL, and KOOS Sports).

Post Hoc Exploratory Analyses

Recent evidence[28] suggested that female, but not male, participants post–ACLR were less physically active than uninjured control participants. Therefore, we stratified our cohort by sex and symptoms into 4 subgroups: symptomatic women, asymptomatic women, symptomatic men, and asymptomatic men. We computed 1-way analyses of variance with Bonferroni post hoc comparisons for all descriptive and outcome variables among subgroups before the post hoc analyses. We then conducted separate univariate linear regressions with each PA variable as a separate predictor variable and the KOOS-QOL as the criterion variable. For supplementary analyses, we calculated similar post hoc regressions for the other KOOS subscores (KOOS Symptoms, KOOS Pain, KOOS-ADL, and KOOS Sports). The α level for all analyses was set a priori at $\leq .05$, and SPSS (version 21.0; IBM Corp) was used for all analyses.

RESULTS

We screened 150 individuals via telephone or email to determine study eligibility (Figure 1) and scheduled 76 participants for a laboratory visit. A total of 66 individuals completed all aspects of the study. For our secondary aim, 36 individuals were classified as asymptomatic and 30 as symptomatic. The symptomatic group demonstrated lower KOOS subscores (t_{65} range = 5.42–8.80; $P \leq .05$) and less time post–ACLR ($t_{65} = 2.22$, $P = .03$) than the asymptomatic group did (Table 1). No differences existed between groups for the other outcome or descriptive variables.

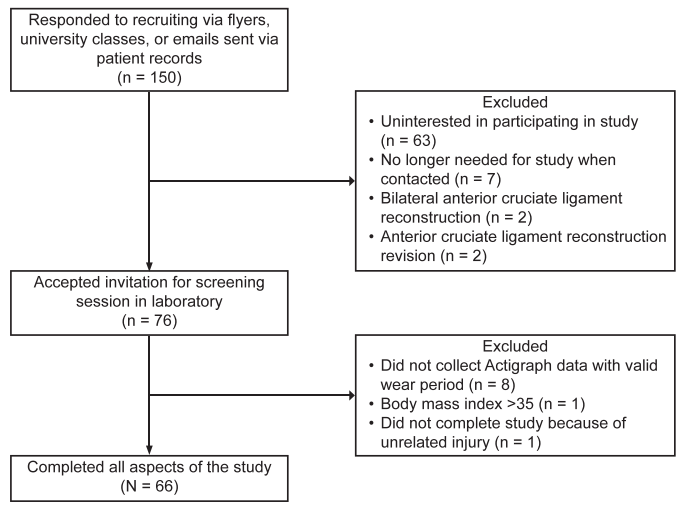

Figure 1. Consolidated Standards of Reporting Trials statement flowchart. ActiGraph, model GT9X Link triaxial accelerometer (ActiGraph, LLC).

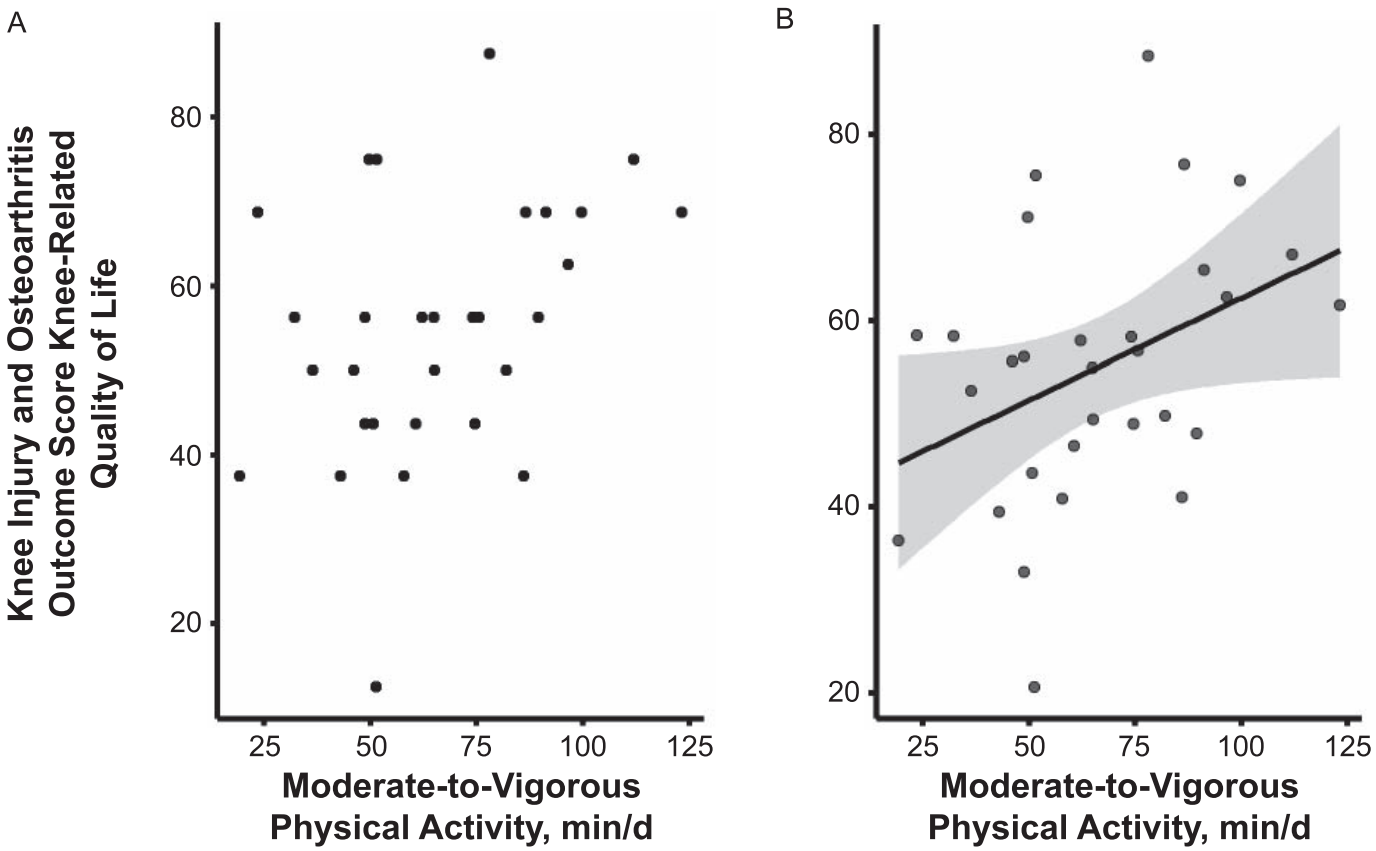

Figure 2. Symptomatic individuals with anterior cruciate ligament reconstruction (ACLR) who demonstrated greater Knee Injury and Osteoarthritis Outcome Score Knee-Related Quality of Life (KOOS-QOL) spent more time spent in moderate-to-vigorous physical activity (MVPA). A, Simple scatterplot of KOOS-QOL versus time in MVPA. B, Partial residual plot (with confidence bands representing the standard error) of the KOOS-QOL conditioned on age and time post–ACLR versus time in MVPA.

In our post hoc analyses, 19 men were asymptomatic, 11 men were symptomatic, 17 women were asymptomatic, and 19 women were symptomatic. Differences between groups were noted for age ($F_{3,62} = 3.31$, $P = .03$), height ($F_{3,62} = 25.11$, $P < .001$), mass ($F_{3,62} = 14.30$, $P < .001$), time post–ACLR ($F_{3,62} = 5.71$, $P < .01$), and KOOS subscore ($F_{3,62}$ range, 8.11–29.44; $P < .001$; Table 2).

Primary Analyses: Associations Between PA and the KOOS in the Entire Cohort

We did not identify any associations between the KOOS-QOL and daily steps ($\Delta R^2 = 0.01$, $\beta < 0.01$, $P = .50$) or MVPA ($\Delta R^2 = 0.01$, $\beta = 0.07$, $P = .36$). No associations were present between the KOOS-QOL and daily steps ($\Delta R^2 = 0.01$, $\beta < 0.01$, $P = .32$) or MVPA ($\Delta R^2 = 0.01$, $\beta = 0.09$, $P = .29$) after our sensitivity analysis that accounted for meniscal injury history. Additional R and β values for each regression can be found in Supplemental Table 1 (http://dx.doi.org/10.4085/1062-6050.0670-20.S1).

Secondary Analyses: Associations Between PA and the KOOS Stratified by Symptoms

More time in MVPA was associated with a higher KOOS-QOL in the symptomatic ($\Delta R^2 = 0.12$, $\beta = 0.21$, $P = .05$) but not the asymptomatic ($\Delta R^2 = 0.01$, $\beta = –0.05$, $P = .47$; Figure 2) group. We did not identify associations for daily steps and the KOOS-QOL in either the asymptomatic ($\Delta R^2 = 0.02$, $\beta < –0.01$, $P = .40$) or the symptomatic ($\Delta R^2 = 0.08$, $\beta < 0.01$, $P = .12$) group. More time in MVPA was associated with a higher KOOS-QOL in the symptomatic ($\Delta R^2 = 0.13$, $\beta = 0.23$, $P = .05$) but not the asymptomatic ($\Delta R^2 = 0.01$, $\beta = –0.04$, $P = .58$) group after our sensitivity analysis that accounted for meniscal injury history. No associations were observed for daily steps and the KOOS-QOL in either the asymptomatic ($\Delta R^2 < 0.01$, $\beta < 0.01$, $P = .71$) or the symptomatic ($\Delta R^2 = 0.07$, $\beta < 0.01$, $P = .15$) group after our sensitivity analysis. Additional R and β values for each regression can be found in Supplemental Table 1. Results of the supplementary regression analyses conducted for the other KOOS subscales are included in Supplemental Table 2 (http://dx.doi.org/10.4085/1062-6050.0670-20.S2).

Post Hoc Analyses: Associations Between PA and the KOOS Stratified by Symptoms and Sex. More time in MVPA was associated with a higher KOOS-QOL ($R^2 = 0.230$, $\beta = 0.251$, $P = .04$) in the symptomatic female group (Table 3). We did not identify other associations between KOOS-QOL and MVPA (R^2 range = 0.008–0.196; $P \geq .17$) or daily steps (R^2 range = 0.012–0.133; $P \geq .12$) in the asymptomatic male, symptomatic male, or asymptomatic female group (Table 3). Results of the supplementary post hoc regression analyses conducted for the other KOOS subscales are provided in Supplemental Table 3 (http://dx.doi.org/10.4085/1062-6050.0670-20.S3).

Table 3. Associations Between Knee Injury and Osteoarthritis Outcome Score Knee-Related Quality of Life and Daily Steps and Moderate-to-Vigorous Physical Activity in Asymptomatic and Symptomatic Male and Female Groups After Anterior Cruciate Ligament Reconstruction

	Men		Women	
Knee Injury and Osteoarthritis Outcome Score Knee-Related Quality of Life subscale (1–100 scale)	Asymptomatic (n = 19)	Symptomatic (n = 11)	Asymptomatic (n = 17)	Symptomatic (n = 19)
Daily steps				
ΔR^2	0.092	0.044	0.012	0.133
β Value	0.001	0.002	<0.001	0.002
P Value	.21	.54	.68	.12
Moderate-to-vigorous physical activity, min				
ΔR^2	0.045	0.196	0.008	0.230
β Value	0.113	0.371	−0.032	0.251
P Value	.38	.17	.73	.04[a]

[a] Indicates an association ($P < .05$).

DISCUSSION

Contrary to our primary hypothesis, no associations existed between the KOOS-QOL and daily steps and MVPA in the entire cohort. Consistent with our secondary hypothesis, more time in MVPA was associated with better KOOS-QOL in the symptomatic group. When we stratified by sex, an association between more time in MVPA and higher KOOS-QOL persisted in the symptomatic female group. The KOOS-QOL is an important outcome to monitor post–ACLR, because it is associated with better outcomes on clinical tests, such as greater distance on the single-legged hop,[29] and in psychological aspects, such as greater self-efficacy for rehabilitation[29] and readiness to return to sport.[30] However, we are the first to demonstrate an association between more time in MVPA and a better KOOS-QOL in individuals with symptoms post–ACLR. To our knowledge, no PA promotion interventions have been conducted in individuals post–ACLR, yet it is possible that increasing time in MVPA among individuals with symptoms post–ACLR may improve knee function. In a previous study,[12] individuals with KOA demonstrated increases in the KOOS after an 8-week aerobic exercise intervention. We hypothesize that increasing PA will result in improvement in the KOOS among individuals post–ACLR, similar to those with KOA. Future authors should determine whether increasing daily steps and time in MVPA via PA promotion influences knee function.

More time in MVPA was associated with the KOOS-QOL in the symptomatic group. Daily steps, which were not associated with the KOOS-QOL in our study, reflect total PA volume.[31] Only 30% of participants (8 in the symptomatic and 12 in the asymptomatic group) met the common threshold of "10 000 daily steps," suggesting that many individuals with ACLR may need to engage in more daily steps. Although daily steps may still be an important outcome post–ACLR, the KOOS-QOL may be associated with MVPA because MVPA indicates higher-intensity movement.[31] Individuals with symptoms may not make decisions about light PA on the basis of their perceived QOL; however, they may modify time spent in MVPA to avoid the pain and difficulty with knee function that occurs during higher-intensity activities. *Moderate-to-vigorous physical activity* is defined as purposeful movement with a metabolic equivalent of task ≥ 3.0, such as brisk walking, weight training, or an activity that causes an elevated heart rate.[31] In our cohort, 97% of individuals (29 in the symptomatic and 35 in the asymptomatic group) met PA recommendations of 150 min/wk of MVPA for adults aged 18–65 years.[32] Our findings are consistent with those of Bell et al,[11] who found that 97% of the ACLR cohort engaged in at least 150 min/wk of MVPA. Return to sport is one of the most commonly discussed clinical goals for patients post–ACLR;[9] yet little is known about engagement in MVPA post–ACLR. Despite most participants engaging in 150 min/wk of MVPA,[11] approximately 56% of patients still did not return to the same level of competitive sport post–ACLR.[3] Thus, individualized MVPA targets rather than a uniform target of 150 min/wk may be an important clinical outcome to consider during recovery post–ACLR.

In our study, the asymptomatic group post–ACLR did not demonstrate an association between the KOOS and daily steps and MVPA. The asymptomatic group displayed high scores on all KOOS subscores, which decreased the variability of the KOOS in the asymptomatic group. Bell et al[11] noted that knee function measured using the International Knee Documentation Committee score was not associated with daily steps or MVPA in individuals post–ACLR. They did not stratify participants based on symptoms, and most of the cohort exhibited knee function >85%, suggesting that the cohort was mostly asymptomatic, which may explain why no associations were identified.[11] Our investigation was specifically powered to stratify the ACLR cohort on the basis of knee symptoms. We hypothesize that individuals with symptoms are more likely than individuals without symptoms to consciously modify activities to avoid knee pain and discomfort and to adapt to limited function. An alternative hypothesis is that individuals without symptoms modified engagement in PA before enrollment in the study. An individual's decision to engage in MVPA is multifactorial, and how individuals with ACLR make decisions regarding MVPA based on perceived knee function remains unknown. Our results reflect the need for future longitudinal research to evaluate engagement in PA and KOOS-QOL throughout different stages of ACLR rehabilitation.

Our study had some limitations that could better inform future work. Our design was cross-sectional, and we could not determine whether MVPA influenced the KOOS-QOL or the KOOS-QOL influenced MVPA. It is possible that the KOOS-QOL and MPVA can be targeted simultaneously in a clinical setting to improve both outcomes during recovery post–ACLR. Our sample was 6 to 146 months post–ACLR.

We included time post–ACLR as a covariate in all regression models in the primary and secondary analyses because it is associated with the KOOS-QOL, daily steps, and MVPA. The asymptomatic group demonstrated more time since ACLR (39 ± 40 months) than the symptomatic group (16 ± 15 months). Knee-related symptoms may differ in origin based on time post–ACLR; in particular, individuals who are 6 months post–ACLR may experience persistent joint effusion or anterior knee pain specifically related to the ACL injury or reconstruction surgery during some activities. Future authors should assess patients earlier in the recovery process or stratify participants based on time post–ACLR. In our post hoc analyses, the asymptomatic and symptomatic male groups were older and had greater height and mass than the asymptomatic female group. We did not include these descriptive variables as covariates in our post hoc analyses because the preliminary analyses should be viewed as hypothesis generating rather than hypothesis confirming. Although our results indicated that the associations between time in MVPA and knee function may be influenced by sex and symptoms, future studies involving larger sample sizes should be conducted to also determine how multiple covariates affect these relationships. In addition, our findings suggested the need to longitudinally evaluate the KOOS-QOL and MVPA throughout recovery post–ACLR.

CONCLUSIONS

No association existed between the KOOS-QOL and daily steps and MVPA in the entire cohort. When we stratified by symptoms, individuals with symptoms who spent more time in MVPA demonstrated a better KOOS-QOL. When we further stratified by sex, women with symptoms displayed the strongest association between more time in MVPA and a better KOOS-QOL. Patient-reported QOL and MVPA may be outcomes to target via therapeutic interventions in individuals with symptoms post–ACLR, either separately or simultaneously.

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