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Feasibility and Acceptability of Implementing a Progressive Walking Program after ACL Reconstruction: A Mixed Methods Study

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Abstract

Context: Individuals after anterior cruciate ligament reconstruction (ACLR) participate in less physical activity compared to uninjured peers. Physical activity in this population is important for both short and long-term health, particularly to reduce the risk of chronic conditions (*eg*, obesity, osteoarthritis).

Objective: The purpose of this study was to assess the feasibility and acceptability of implementing a walking program early after ACLR.

Design: Explanatory Mixed Methods Study

Setting: Telehealth

Patients or Other Participants: Ten individuals (60% female, mean age 20.2 ± 3.9 years old, mean BMI 22.6 ± 2.9 kg/m^2) within 8 weeks of a unilateral ACLR

Intervention: A 12-week personalized progressive walking program to increase daily steps utilizing weekly virtual visits with a physical therapist.

Main Outcome Measures: Quantitative data included rates of appointment attendance, activity monitor wear compliance, adverse events, and achievement of daily step goals. Qualitative analysis of field notebooks collected throughout the intervention and semi-structured post intervention interviews were performed to explain the quantitative feasibility metrics using a case study approach.

Results: Participants wore their activity monitor 92.3% of days, attended 94.2% of appointments, met their recommended physical activity goal 54.8% of days, and 50% of individuals reached their physical activity target at least 50% of weeks. No adverse events related to the walking program were reported. Program-level and participant-level themes that promoted successful physical activity goal achievement were identified.

Conclusions: This study demonstrated mixed feasibility and acceptability of a progressive walking program early after ACLR. Participants demonstrated high adherence to wearing an activity monitor and completing weekly virtual physical activity program sessions. However, daily physical activity goals were only met approximately half of the time. Clinicians and researchers can use the themes identified from the qualitative analysis in future program designs to promote physical activity after ACLR.

Key words: physical activity; rehabilitation; telehealth

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Key Points:

- Participation in a progressive walking program early after ACL reconstruction was safe and without adverse events.
- Interventions to increase physical activity need to account for differences between patients (*eg*, daily schedule, individual response to goal setting) to promote success.
- Interventions to increase physical activity need to provide the structure (*eg*, flexible and periodic visit options, motivational interviewing) to promote success.

Introduction

Anterior cruciate ligament (ACL) injuries and subsequent ACL reconstructions (ACLR) have increased as much as 143% worldwide.[1-4] Many who undergo an ACLR are under the age of 30 years old.[1,3,4] After ACLR, individuals are at risk for reduced physical activity participation,[5-8] function,[9] and quality of life.[10] It is important to understand avenues to mitigate lifelong health-related issues in young, otherwise healthy individuals with ACLR.

The World Health Organization recommends 60 minutes per day of moderate-to-vigorous physical activity for individuals 5-17 years old and 150 minutes per week of moderate-to-vigorous physical activity per week for adults 18-64 years old.[11] Despite established recommendations, individuals who have had an ACLR regularly participate in less physical activity.[5-8] Those within three years of ACLR record up to 3000 less steps per day than their uninjured peers,[5,6] with almost 15 minutes per day less spent in moderate-to-vigorous physical activity.[5] Among females, those with ACLR are 2.5 times more likely than their uninjured peers to not reach World Health Organization recommended physical activity levels.[7] Improving physical activity in this population is vital for enhancing long-term knee and overall health and to reduce potential complications related to low activity levels, such as impairments with mental health, cardiorespiratory and muscular fitness, bone health, cardiometabolic health, cognitive function, and obesity.[12,13]

Recent efforts have been made to implement an intervention to increase daily step counts in individuals with ACLR, shortly after total knee arthroplasty, and those with symptomatic knee osteoarthritis. Kuenze and colleagues found that individuals within five years of ACLR were compliant with wearing a wrist-worn activity monitor but did not reach personalized daily step count targets, demonstrating that using a wrist-worn activity monitor was feasible, but text messages may not lead to increased physical activity.[14] In their study, individuals were provided a daily step target via text message based on their previous days' steps, but otherwise did not have regular check-ins with a healthcare provider regarding their physical activity.[14] Christiansen and colleagues found that individuals with a recent total knee arthroplasty were able to increase their steps over a year.[15] Individuals who had weekly conversations with their physical therapist until discharge and then monthly phone calls for an additional six months had almost 1800 more steps per day than a control group, demonstrating that check-ins were feasible for patients and contributed to increased physical activity.[15] Stanton and colleagues found that older adults with symptomatic knee osteoarthritis were able to increase their daily step counts 10% from their baseline assessment.[16] These individuals met weekly with a physical therapist for the first four weeks of their program and received coaching on reaching their physical activity goals. Taken together, the combined results from these studies demonstrate that implementing a physical activity intervention with individuals after ACLR is possible with a wrist-worn activity monitor, but implementation may require consistent coaching to help them increase their physical activity over the course of time.

To our knowledge, no study thus far has investigated the feasibility of implementing or impact of a program to increase physical activity in the early stages of recovery after ACLR, nor considered participant perceptions to help understand the experience of increasing physical activity after surgery. Therefore, the purpose of this mixed methods case study[17] was to quantitatively assess the feasibility of implementing an intervention to increase physical activity early after ACLR and to qualitatively understand the participant experience with the intervention and increasing their physical activity after surgery. Results of this research will provide an outline for future physical activity interventions designed with patient input to be tested early after ACLR.

Methods

An explanatory, mixed methods case study approach was used for this study (Figure 1). This approach allowed for the collection of quantitative data regarding the feasibility of a personalized progressive physical activity program as well as the collection of follow-up qualitative data to understand the thoughts and feelings of the individuals who participated in the program. This combination of data provides a fuller understanding of the current physical activity program and insights to develop and guide any potential adaptations to the program for application with future patients.

Participants

Participants within eight weeks of ACLR were recruited from physical therapy clinics within 75 miles of the host site. An emergent volunteer sample of participants who met our inclusion criterion was identified through a network of providers the research team established specifically for this study.[18] This included physical therapists and orthopedic surgeons. This distance allowed an investigator to travel to participants for in-person enrollment and for training the participant to use the activity monitor (Actigraph GT9x, Actigraph Corp, Pensacola, FL, USA) and associated phone application (CentrePoint, Actigraph Corp, Pensacola, FL, USA). During the in-person enrollment session, participants also practiced accessing the encrypted Zoom link (Zoom Video Services, Inc, San Jose, CA, USA) needed for virtual appointments throughout the study. Individuals were included if they were between the ages of 13-35 years old and within two weeks of full weightbearing clearance from their surgeon (range of two to eight weeks after ACLR), regardless of activity level prior to injury. Individuals were excluded if they had a concomitant surgical procedure that included extended weightbearing restrictions beyond eight weeks or a BMI greater than 35 kg/m^2. While enrolled in the study, individuals performed physical therapy with clinicians unaffiliated with the study who used their own protocols without input from the study. All participants provided written informed consent as approved by the Institutional Review Board at the XXX (IRB# 215-20-EP).

Physical Activity Monitor

An Actigraph GT9x wrist-worn accelerometer was worn by each participant for the duration of the study. Participants were instructed to wear their activity monitor for all waking hours that they were not in water. Each evening, participants were instructed to use the associated phone application to upload their physical activity data to the encrypted cloud-based server. Data were processed within the CentrePoint cloud-based software. For a valid day of wear, participants were required to wear the activity monitor for at least ten hours. Daily steps were calculated from the wrist-worn accelerometer each day and reported back to the participant weekly as part of their weekly coaching sessions.

Intervention

Participants completed a novel 12-week physical activity intervention developed for this study. This included a two-week baseline assessment of their physical activity in which daily step counts were established using the wrist-worn accelerometer. The two-week baseline assessment was used to create a personalized physical activity program to increase each participant's average daily steps by 10% each week until 10,000 steps per day were achieved (Table I). An increase in daily steps by 10% each week was decided upon as it had been deemed an "easy goal" in previous studies[19] and the participants in the current study had a recent knee surgery limiting the ability to progress more quickly. The end target of 10,000 steps per day was chosen as it is deemed an appropriate target for healthy adults[20] and many individuals with an ACLR are healthy and physically active prior to their injury. To achieve 10,000 steps per day by the end of the intervention, a participant would need to average 3186 steps per day during the two-week baseline period (Table IA). If a participant were to have less than 3186 steps per day at baseline, their average step count was re-assessed halfway through the intervention (weeks five-six). This reassessment used the average number of steps per day taken during weeks five and six and compared it to the seven-week step target established at baseline. If the average of the actual step counts from weeks five and six was higher than the initial target step count for week seven, then the seven-week step count target was changed to a value equal to 10% greater than the average step counts taken during weeks five and six. For example, if a participant averaged 2500 steps during the baseline period, the preset targets would not reach 10,000 steps per day. However, if they had taken 5600 and 6100 steps per day during weeks five and six, respectively, the average would be 5850 steps per day. A 10% increase from 5850 steps per day would then be used to set the remaining progression starting in week seven (Table IB). For participants with greater than 3186 steps per day at baseline, the weekly percent increase in daily steps was reduced to 5% after reaching 10,000 steps to prevent excessively high step counts (Table IC). A 5% increase was continued to limit potential restriction of activities while not expecting participants to continue a high level of progression of activities.

Weekly virtual visits with a licensed physical therapist with over ten years of orthopedic experience (DW) began once each participant completed their baseline assessment and the individualized physical activity progression was established. Each visit consisted of an assessment of potential adverse events (*eg*, a conversation and visual inspection to assess for knee joint effusion, increased knee joint pain, and reduced knee range of motion), discussion of the ability to achieve the previous week's step goal, a discussion of the upcoming step goal, and strategies to use to promote physical activity for the upcoming week. If an adverse event was noted, the physical therapist was instructed to record the adverse event for tabulation at the end of the study. The physical therapist used a motivational interviewing approach for promoting physical activity with all participants. This included empathizing, assisting in problem solving, and identifying solutions to help guide participants towards increasing their physical activity.[21] After each visit, participants were sent either an email or a text message, based on participant preference, with their personalized step target for the next week. Criteria for progression of the walking program was solely based on knee symptoms. To assess symptoms, participants rated their knee soreness at rest and during walking on a 10-point numeric rating scale. Participants had their daily step goals progressed if they did not have an increase of more than 2/10 in knee soreness during walking compared to reported knee soreness at rest in the previous week.

Outcomes

Quantitative

The quantitative data for this analysis served two purposes. One purpose was to assess the feasibility of implementing a walking program to increase physical activity early in rehabilitation after ACLR. These outcome variables included the percentage of participants recruited who ultimately enrolled, the percentage of weeks with at least 5 days of valid activity monitor wear (≥ ten hours per day), and the percentage of weekly virtual visits attended. The second purpose was to assess the impact of the specific walking program designed for this study. These outcome variables included the percentage of weeks that the daily step goal was achieved, the percentage of participants that achieved a daily average of 10,000 steps during at least one week of the physical activity intervention, and the number of adverse events throughout the intervention. Outcome measures were then combined in the mixed methods analysis to provide an overall picture regarding implementation and participant response to an intervention to increase physical activity after ACLR.

At the end of the intervention, knee function was measured descriptively using the International Knee Documentation Committee (IKDC) form. The IKDC is a valid and reliable test for knee function after ACLR.[22] The IKDC is scored from 0-100% with higher scores indicating more function. Participant scores were compared to previously established cutoff scores to help describe participant-reported knee function compared to established scores[23] to identify individuals functioning well at the end of the intervention, which was then used in the mixed methods analysis.

Qualitative

Two avenues of qualitative data were collected. During the intervention, the physical therapist (DW) kept field notebooks to track real time thoughts, trends, and participant comments. After the completion of the intervention, individuals completed a semi-structured virtual interview (with DW), who was trained in semi-structured interview techniques by an expert in mixed methods study design and implementation (Supplemental Figure 1). These interviews were recorded, transcribed, and then checked for accuracy. Transcripts were then imported into MaxQDA software (MaxQDA 2022, VERBI GmbH, Berlin, Germany). Field notebooks were used to help generate the provisional code list for the interviews.[24] Pattern coding was then used for the semi-structured interviews to refine the code list and identify the themes.[24] Trustworthy strategies included triangulation of multiple sources of data (field notebooks and interviews with quantitative data) and peer debriefing with multiple qualitative experts.[25] Peer debriefing is a process where a researcher engages in reflective conversation with a peer familiar with the phenomenon, but uninvolved with the study to identify weak connections or missed opportunities during analysis of qualitative data.[25] During the development of themes and common codes, two peers were used. As the analysis continued, regular meetings were held between the PI (DW) and one peer debriefer (MCH) to review codes, discuss emerging themes, and develop strategies for representing the qualitative findings.

Analysis

Quantitative data for each participant was analyzed prior to their semi-structured interview. This allowed for the discussion of the participant's performance during the semi-structured interview to glean important information regarding patient understanding of performance during the intervention. Quantitative feasibility outcomes were compared to the following thresholds established *a priori*: 50% of recruited individuals enrolled in the study, ≥ 80% of weeks with at least five days of valid wear, ≥ 80% of weekly Zoom visits attended, ≥ 80% of weeks that daily step targets were reached, and ≥ 80% of participants who reached 10,000 steps by the end of the intervention.[14]

The transcripts of each participant were read for understanding with common themes noted. After themes were identified, a single case study[26] narrative was created for each participant that integrated their quantitative participation and goal data as well as their qualitative interview data and researcher's field notes. The narratives were then combined to understand broader trends and themes for the entire group.

Results

A total of 15 individuals were recruited with ten (67%) enrolling. Participants were 60% female with a mean age of 20.2 (standard deviation [SD] ± 3.9) years old and a mean BMI of 22.6 (SD ± 2.9) kg/m^2. Demographic and clinical data are presented in Table II. IKDC scores at the end of the walking program ranged from 53.3 to 100%.

Quantitative

Quantitative feasibility metrics combining an assessment of the feasibility and impact of implementing the intervention are presented in Table III. In summary, the wrist-worn activity monitor was worn during 87.5% of weeks (including the two additional weeks for the baseline assessment period for each participant), with 94.2% of all virtual visits attended. The weekly step goal was met 46.2% of the time. No adverse events (*eg*, knee joint effusion, increased knee joint pain, reduced knee range of motion) related to the walking program were reported from any participant throughout the physical activity program. Two participants had increased knee effusion, but both instances were related to recent activities outside of the physical activity program (*ie,* one instance of trying to increase running too early, and one instance of lifting too aggressively in the gym). A total of 25 days of data across all participants were lost due to device malfunctions. These malfunctions included breakage of the watch band (10 days), battery charge issues (11 days), and crashing of the device (4 days). These days were removed from the feasibility analysis. (Table IV).

Qualitative

Programmatic Factors that Supported Success

Across all participants, there were common programmatic factors that either helped participants be successful in reaching their step goals or could be modified to better help success. These themes included: *weekly virtual visits provided accountability, motivational interviewing and positive feedback helped,* and *increasing walking early after surgery was helpful for long-term success.*

Weekly Virtual Visits Provided Accountability

Having a weekly virtual visit to attend was viewed as a positive factor for achieving step goals. Many felt that the weekly meetings “set the tone for the week” (P9) and “helps me be accountable” (P10). Some felt that without the weekly visit they would have been less motivated to strive for their step targets. Additionally, the weekly visits provided emotional support to reduce anxiety about any program related questions. If a participant had any questions that arose at any point, they “could just ask” (P6) at the next visit. Lastly, the virtual nature of the visits was “definitely better” (P1) than in-person as it allowed for flexibility in meeting location and timing.

Motivational Interviewing and Positive Feedback Helped

The incorporation of motivational interviewing techniques and focusing on positive feedback was welcomed by all participants. The motivational interviewing included directed questions to help participants discover their own motivation and commitment to change.[21] This helped provide “the support for the experience” (P5) of the walking program. Going through the barriers to walking assisted participants in identifying new strategies for improving their steps. For instance, one participant had difficulty walking on days where she would sleep in. She was able to identify going to bed earlier as a strategy to help her wake up earlier and go on a walk to start her day. Additionally, the positive reinforcement helped individuals feel like they were “actually doing something and progressing” (P3).

Increasing Walking Early after Surgery Was Helpful for Long-Term Success

By the end of the walking program, many individuals believed that increasing their walking in the early stages after ACLR was not only safe but was good for their long-term outcomes. Many individuals described positive benefits, such as walking felt “nice on my knee” (Participant 2 [P2]) and would help their knee “get more fluid” (P6). Additionally, many thought they progressed more smoothly throughout rehabilitation as it helped them feel stronger. The act of increasing their walking helped them be able to “handle the transition back to school” (P10) full-time and “really helped with the transition to running” (P7). There were also psychological benefits reported. By the end of the program, multiple participants reported “liking my walks” (P6). Other participants found that walking helped them realize that they were doing well and not as fragile as they had originally thought - “I would walk a bit and go ‘Oh wow’ because my knee wasn’t sore” (P7).

<u>Participant Characteristics that Impacted Success</u>

There were three common participant-level characteristics that helped understand participant success in achieving their weekly step targets from the physical activity program: *Competitive sports participation, control over their schedule,* and *response to weekly step goals.* (Figure 2).

Competitive Sports Participation

Participants who were involved in competitive athletics at the time of injury were more likely to achieve the step targets assigned throughout the physical activity program. The aspect of setting exercise goals aligned with participants' previous experiences with sport and "being an athlete" (P6), while helping participants "get back into the athlete head zone" (P5).

While most participants with competitive sports involvement were motivated by the progressive nature of the goals, one participant diverged from this theme. This participant was a high school football player at the time of injury. While he was regularly able to achieve the step targets provided, he did not feel he needed to try hard as, "Ever since I started working, I've been hitting my step goals every day"(P1).

Control Over Schedule

Whether or not a participant felt they had control over their daily schedule emerged as a theme that impacted success in achieve step count targets. Participants that had more flexibility in their schedule felt more able to fit in walking at various times throughout the day. Some participants would "walk on like treadmills during weightlifting class" (P7) with multiple individuals incorporating walking around the house when watching television in the evening (P1,5,10).

Participants who had less flexibility in their day struggled to find time to walk, despite their best efforts. "I would walk during my lunch break just to try and get steps" (P8). However, even with attempts to walk more, those with more strict daily schedules struggled to find time for walking, leading individuals to frustratingly ask, "Where do I get those steps?" (P9) after a workday.

This phenomenon was most evident with P2. He began the program while in college and transitioned to full-time employment halfway through the physical activity program. In the early stages of the program, when he had more flexibility in his schedule, he "would go for walks at 11 p.m." However, when he began his full-time employment, he was "on my feet standing still for around 12 hours." Quantitatively, he had a significant drop in success of increasing his daily steps once he began full-time employment.

Response to Weekly Step Goals

The personal response that each participant had to the progressively increased goals impacted how often they achieved their goals. While some participants were neither motivated nor disheartened by the goals, most individuals were either motivated or deterred by the goals.

For some participants, the goals provided "something to look forward to" (P6), encouraging activity and reducing sedentary time – "Without the goal I would have just sat around more' (P5).

Other participants found it difficult to keep up with the increasing daily step goals, leading to discouragement. If participants were struggling to increase their step counts as the step goal progressed, some "got dismotivated *[sic)]*…because it was pretty much impossible for me to reach" (P9) the continuously progressing goals. Other individuals were able to do forms of physical activity that did not register as steps (such as cycling). This led to frustration as "it would never give me credit for cycling so it would look like I was a bum" (P8).

One area that could have potentially impacted the response to goal was the ability to track physical activity beyond steps. Some participants struggled with achieving their walking goals because they preferred physical activity that did not register as increasing daily steps and wanted the program to include other activities besides walking. Some individuals preferred to use a stair master, but acknowledged they missed out on "probably thousands of steps" (P2). Others reported a preference for strength training or cycling, neither of which would inherently increase the daily step count and made individuals "feel like that exercise was wasted" (P8).

Discussion

This mixed methods study aimed to assess the feasibility and acceptability of implementing an intervention to increase physical activity early after ACLR. Completing a progressive walking program following full weightbearing clearance after ACLR was safe, with mixed results regarding feasibility of program implementation. While participants wore a wrist-worn accelerometer and attended virtual visits, they inconsistently achieved their step goals. Participants reported no adverse events with the walking program, and some believed that completing the program improved mobility, strength, and comfort in their ACL-injured knee. These themes, identified in Table V can inform future physical activity intervention development.

The quantitative feasibility metrics demonstrated mixed results. Implementation of the intervention demonstrated some success in that recruitment was successful with >50% of individuals recruited ultimately enrolling and 100% completing the intervention and post-intervention interview. The wrist-worn activity monitor was worn on most days. This wear compliance (96.2% of days) is similar or better than wear compliance in individuals 5-19 years old (15-92% wear compliance),[27] higher than most studies investigating adults working a sedentary job (59 to 94%),[28] and similar to individuals on average three years after ACLR (95.5 to 97.7%).[14] Additionally, the wear compliance in the current study was impacted by 25 days of activity monitor malfunction (*ie,* band breaking or device crashing and requiring in-person reset), indicating that wear compliance may have been even higher without the activity monitor malfunctions. Our findings suggest that wear compliance is likely to be high for future studies involving a wrist-worn activity monitor in a young population after ACLR.

The current cohort had difficulty achieving the daily or weekly step goals from the specific intervention in this study. Participants did not regularly achieve their daily or weekly step goal at the targeted thresholds set at program initiation. However, the percentage of days (56.4%) that participants achieved the recommended step target is greater than most physical activity interventions elicited in a systematic review of physical activity interventions in adolescents (35-

54%).[29] The current cohort also achieved their weekly step target more often than individuals three years after ACLR (31.5 ± 6.8%).[14] Additionally, individuals in the current study demonstrated an average increase of 3827 steps per day over 12 weeks, resulting in a 94% increase in physical activity from baseline to post-intervention. This 12-week increase in physical activity is greater than most attempts to increase physical activity in younger individuals,[27,29] adults with sedentary jobs,[28] or individuals after ACLR.[14] In a cohort of individuals with a history of ACLR, a 28-day intervention to increase daily steps resulted in an overall 3.0% decrease in daily steps compared to the 28-day baseline assessment.[14] Our study differed from the study by Kuenze and colleagues in that we included a weekly virtual visit and messaging about goals consistent with participant preference, both methods recommended by the authors to improve compliance.[14] Another important consideration when interpreting our findings is that the cohort began their physical activity intervention at a time where their physical activity was inhibited due to a recent surgery and not necessarily due to behavior. However, in a group of individuals over the first year after total knee arthroplasty, an intervention to promote physical activity only led to a 20% increase in physical activity,[30] much less than the 94% increase in the current study. The current feasibility study was not designed for a group comparison so we do not yet know if this physical activity intervention might affect step counts compared to no intervention. An appropriately designed and well-powered future study is needed to determine the impact of the physical activity intervention.

The semi-structured interviews and field notebooks, combined with the quantitative data, provided important information for improving future interventions to increase physical activity after ACLR (Table IV). These future interventions should consider both program-level and patient-level characteristics to improve likelihood of successfully increasing physical activity.

Future physical activity interventions after ACLR should have procedures and progression algorithms that allow for better participant engagement. Periodic visits combined with motivational interviewing provides accountability and strategies for participants to achieve their activity goals. Motivational interviewing improves physical activity in a variety of individuals.[31,32] Additionally, motivational interviewing can impact self-efficacy, which has been related to physical activity progression in individuals with rheumatoid arthritis.[33] Educational materials on the benefits of increasing physical activity, which could use patient quotes from the current study, would help future participants understand the benefits and need for increasing their physical activity. Allowing patients to participate in goal setting and having a personalized progression algorithm based on previous success in reaching physical activity goals may help individuals who would otherwise become disheartened by a standardized goal progression perceived to be out of reach. A progression algorithm that requires successful goal achievement prior to increasing physical activity targets has successfully been used to increase physical activity in individuals after total knee arthroplasty[15] and may be more effective than the progression algorithms used in this study. Lastly, additional avenues to track physical activity other than daily step counts, such as cycling or stair climbing, would allow individuals to perform their preferred form of physical activity, and may result in a greater likelihood of successfully engaging patients and achieving physical activity goals.

In addition to the aforementioned procedures and algorithms, future physical activity interventions should account for individual characteristics that impacted success in the current study. Individuals not actively participating in competitive athletics at the time of injury may be less familiar with exercise-related goal setting. Previous reports have found that those who are more active at the initiation of a physical activity intervention may be more likely to increase their physical activity throughout the intervention.[34] Identifying individuals who do not have flexibility in their day to allow for frequent physical activity breaks may require other strategies to increase physical activity. In a systematic review assessing the ability of adults with sedentary jobs to achieve increased physical activity levels, only 56% of studies demonstrated increases in physical activity.[28] This demonstrates the importance of identifying barriers to physical activity in working individuals to better facilitate achievement of their physical activity goals. Additionally, future work should aim to understand how the individual is internalizing the physical activity goals in the early stages of the program in order to identify those who may be disheartened by the progressive physical activity targets. Lastly, an understanding of the participant's preferred mode of physical activity will help providers direct individuals towards the activities most likely to lead to success in promoting increased physical activity.

This study is not without limitations. As the intervention required participants to be able to access a smartphone app and an encrypted Zoom link for virtual visits, those without a smartphone or adequate access to internet may not have responded to recruitment information. Three of the four male participants had fixed schedules for most of the study. While it is possible that there was a difference between male and female participants in response to daily schedule flexibility, female participants with fixed scheduling had similar issues to their male counterparts. Additionally, the participant who changed their schedule type at the halfway point of the study was male and had more success in the first half of the study when his schedule was more flexible. Although data saturation during the qualitative analysis was met, the small sample size could limit generalizability regarding feasibility metrics.

Conclusion

This study demonstrated the feasibility and safety of a walking intervention initiated early after ACLR upon clearance to full weightbearing. Individuals in the current study wore a wrist-worn activity monitor, increased their physical activity, and achieved recommended step goals at a higher percentage than previous interventions to improve physical activity. This study identified programmatic themes (*weekly virtual visits provided accountability, motivational interviewing and positive feedback helped, increasing walking early after surgery was helpful for long-term success)* and participant level themes (*competitive sports participation, control over* *their schedule, and response to weekly step goals*) to help increase physical activity after ACLR. Results provide the framework to test future physical activity interventions after ACLR.

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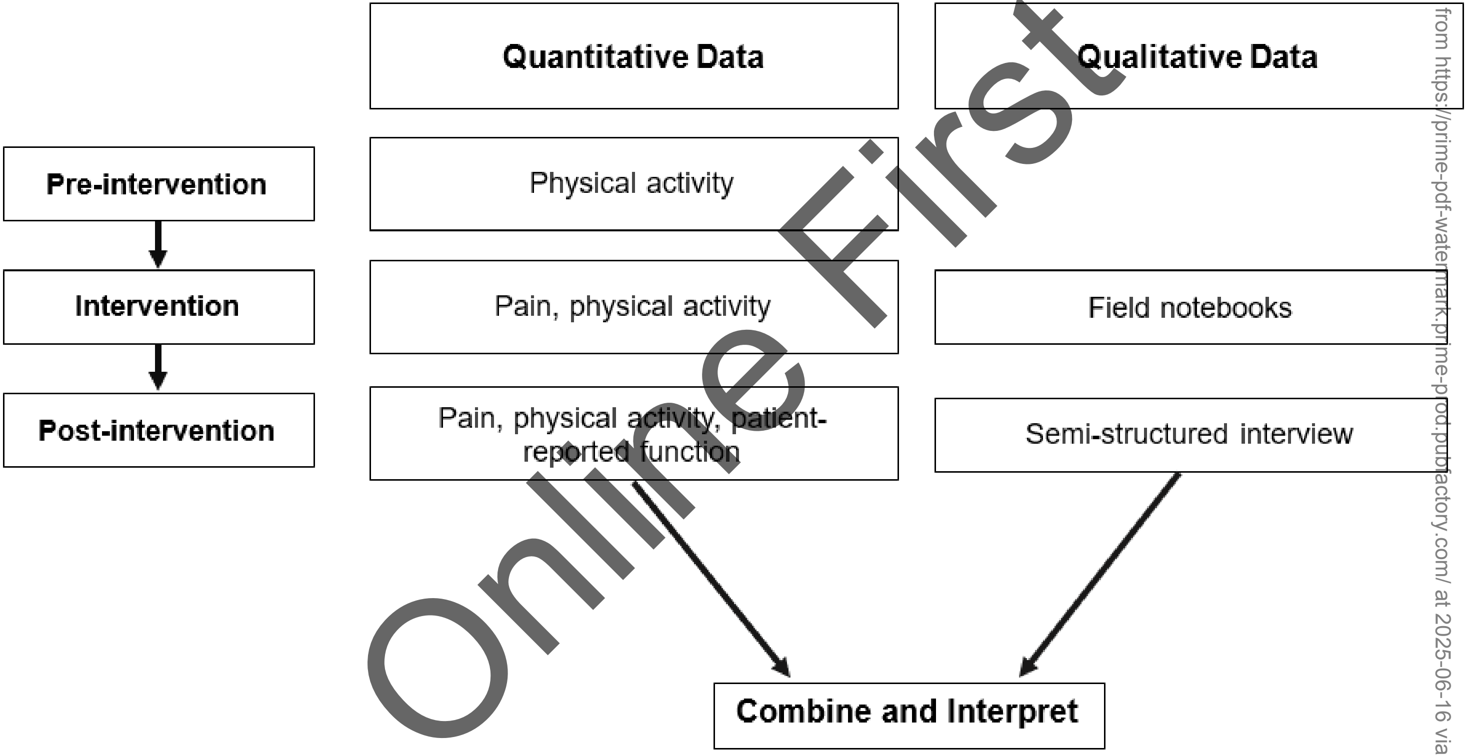
Figure 1: Procedural diagram of mixed-methods study design.

Figure 2: Combined feasibility, qualitative descriptions, and subjective report of knee function at end of intervention.
Abbreviation: IKDC: International Knee Documentation Committee Form.
Percentage of weeks with goal hit threshold: 50%; IKDC threshold: compared on age-matched norms[22]


Quantitative Data
Qualitative Data
Pre-intervention
Physical activity
Intervention
Pain, physical activity
Field notebooks
Post-intervention
Pain, physical activity, patient-reported function
Semi-structured interview
Combine and Interpret

Participant	Athlete at time of injury	Control over schedule	Response to provided goals	Percentage of weeks with goal hit	IKDC
1	Athlete	Flexible Schedule	Indifferent	67%	64.1
2	Athlete	Schedule Changed	Motivated	50%	64.4
3	Nonathlete	Fixed Schedule	Indifferent	58%	55.2
4	Nonathlete	Fixed Schedule	Discouraged	0%	100.0
5	Athlete	Flexible Schedule	Motivated	75%	66.3
6	Athlete	Flexible Schedule	Motivated	33%	53.0
7	Athlete	Flexible Schedule	Motivated	25%	80.4
8	Nonathlete	Fixed Schedule	Discouraged	17%	58.6
9	Nonathlete	Fixed Schedule	Discouraged	25%	59.8
10	Athlete	Flexible Schedule	Motivated	100%	59.8

Contributed to success in achieving step targets

Contributed to difficulty in achieving step targets

Did not contribute to step target achievement

Above pre-defined threshold

Below pre-defined threshold

Table I: Examples of daily step progression. A) Typically expected progression, B) adjustment at week 7 if low baseline, C) Slowing of progression once 10000 steps/day.

A. Typical Progression (Baseline 3186 steps/day)			B. Low Baseline (Baseline 2500 steps/day)		C. High Baseline (Baseline 4500 steps/day)	
Week	Daily Step Goal	Next Week Increase (%)	Daily Step Goal	Next Week Increase (%)	Daily Step Goal	Next Week Increase (%)
1	3505	10	2750	10	4950	10
2	3856	10	3025	10	5445	10
3	4241	10	3328	10	5990	10
4	4665	10	3660	10	6588	10
5	5132	10	4026	10	7247	10
6	5645	10	4429	10	7972	10
7	6209	10	6500	10	8769	10
8	6830	10	7150	10	9646	10
9	9513	10	7568	10	10611	5
10	8265	10	8652	10	11141	5
11	9091	10	9517	10	11698	5
12	10000		10468		12283	

Table II: Participant demographic and clinical information

	Frequency or Average (SD)
Female:Male	6:4
Age (years)	20.2 (3.9)
BMI (kg/m^2)	22.6 (2.9)
Time from ACLR to enrollment (weeks)	5.3 (1.9)
Pre-Intervention daily steps	4071.1 (1543.4)
Post-Intervention daily steps	7898.1 (2564.1)
Post-Intervention IKDC Score	66.2 (14.1)

Abbreviations: SD: standard deviation; BMI: body mass index; kg: kilograms; m: meters; ACLR: anterior cruciate ligament reconstruction; IKDC: International Knee Documentation Committee Subjective Knee Form 2000.

Table III: Quantitative feasibility metrics for progressive physical activity program				
	Achieved	**Potential**	**Percentage**	**Feasibility Benchmark**
Individuals enrolled	10	15	67%*****	50%
Days of valid wear	919	955	96.2%*****	80%
Weeks of valid wear	120	137	87.5%*****	80%
Days step goal met	460	815	56.4%	80%
Weeks step goal met	54	117	46.2%	80%
Zoom visits attended	113	120	94.2%*****	80%
Individuals at 10,000 steps	4	10	40.0%	80%

*** -** indicates achieved percentage greater than *a priori* thresholds

Table IV: Days with data missing due to activity monitor malfunction

Reason	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Broken watchband	4	-	6	-	-	-	-	-	-	-	10
Battery charge issue	-	5	-	-	-	-	-	-	6	-	11
Device software crash	-	-	-	4	-	-	-	-	-	-	4

Table V: Qualities of a future physical activity intervention

Program characteristics to include	Patient characteristics to consider
Periodic visits with healthcare professional (potentially virtual)	Current involvement in competitive athletics
Motivational interviewing	Flexibility in daily schedule
Education on benefits of increasing activity	Patient response to goals
Patient participation in goal setting	Patient-preferred form of physical activity
Personalized progression based on goal reaching	
Ability to track physical activity beyond steps	

<table>
<tr><th>Primary Question</th><th>Prompts and Probes</th></tr>
<tr><td colspan="2">Why did you participate in the walking program?</td></tr>
<tr><td colspan="2">What was it like to participate in the walking program? Tell me about your experience.</td></tr>
<tr><td>How do you think the walking program impacted your knee?</td><td>– How did the program help your knee?
– Was there anything in the walking program that you thought hurt your knee? If so, explain.</td></tr>
<tr><td>What was it like to wear the watch?</td><td>– In what ways do you feel it was easy?
– In what ways do you feel it was difficult?</td></tr>
<tr><td>What was your experience like trying to reach your weekly goals?</td><td>– In what ways do you feel you were successful?
– In what ways do you feel you had difficulty?</td></tr>
<tr><td>Show participant graphical visualization of steps per day and goal reaching success.</td><td>– Specific prompts on visualization of participant performance</td></tr>
<tr><td>How has this program impacted your feelings on physical activity?</td><td>– Do you feel like increasing your physical activity is specifically good for your knee?
– How did you feel about physical activity prior to your injury?</td></tr>
<tr><td>What suggestions do you have to improve the program?</td><td>– What are parts of the program that worked well for you?
– How did the virtual nature impact your experience?</td></tr>
<tr><td colspan="2">Is there anything else that you think I should know about your experience to help me improve this program?</td></tr>
</table>