Archives of Rehabilitation Research and Clinical Translation (2023) 5, 100254

ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Rehabilitation Research and Clinical Translation

Archives of Rehabilitation Research and Clinical Translation 2023;5:100254

Available online at www.sciencedirect.com

Original Research

Demographic and Clinical Correlates of Device-Measured Physical Activity Levels in Individuals with Femoroacetabular Impingement Syndrome

Naif Z. Alrashdi, PT, MSRS, PhD [a,b], Robert W. Motl, PhD [c], Sara Samchok, PT, DPT [d], Amit M. Momaya, MD [e,f], Benton A. Emblom, MD [g,h], Michael K. Ryan, MD [g,h], Matthew P. Ithurburn, PT, DPT, PhD [h,i]

[a] *Rehabilitation Science PhD Program, School of Health Professions, University of Alabama at Birmingham, Birmingham, AL*
[b] *Department of Physical Therapy and Health Rehabilitation, College of Applied Medical Sciences, Majmaah University, Majmaah, Kingdom of Saudi Arabia*
[c] *Department of Kinesiology and Nutrition, University of Illinois Chicago, Chicago, IL*
[d] *TherapySouth Physical Therapy, Birmingham, AL*
[e] *Department of Orthopaedic Surgery, School of Medicine, University of Alabama at Birmingham, Birmingham, AL*
[f] *Sports Medicine, Children's of Alabama, Birmingham, AL*
[g] *Hip Center at Andrews Sports Medicine and Orthopaedic Center, Birmingham, AL*
[h] *American Sports Medicine Institute, Birmingham, AL*
[i] *Department of Physical Therapy, University of Alabama at Birmingham, Birmingham, AL*

KEYWORDS
Exercise;
Femoracetabular impingement;

Abstract *Objective:* To compare physical activity (PA) levels between individuals with femoroacetabular impingement syndrome (FAIS) and uninjured controls and determine correlates of moderate to vigorous physical activity (MVPA).
Design: Cross-sectional, comparative study.

List of abbreviations: ACSM, American College of Sports Medicine; BMI, body mass index; FAIS, femoroacetabular impingement syndrome; HOOS, Hip Disability and Osteoarthritis Outcome Score; iHOT-12, International Hip Outcome Tool; MVPA, moderate to vigorous physical activity; NPRS, numeric pain rating scale; PA, physical activity.

Presented as an abstract to the American Physical Therapy Association, February 2-5, 2022; San Antonia, TX.
Funded by the University of Alabama at Birmingham School of Health Professions Junior Faculty Research Grant. Mr Alrashdi's PhD studies were supported by the Saudi Arabian Cultural Mission.
Disclosures: Dr Emblom has received royalties and consulting fees from Arthrex, unrelated to the current work. Dr Ryan has received consulting fees from Arthrex and Zimmer Biomet, speaker fees from Arthrex and Zimmer Biomet, and education payments from Arthrex, DJO, and Smith & Nephew, unrelated to the current work. The other authors have nothing to disclose.
Cite this article as: Arch Rehabil Res Clin Transl. 2023;000:100254

https://doi.org/10.1016/j.arrct.2023.100254

Rehabilitation

Setting: University laboratory.
Participants: A total number of 25 individuals with FAIS (15 female; age, 31.0±9.2 years; symptom duration, 4.7±7.1 years) and 14 uninjured controls (9 female; age, 28.0±9.1 years) (N=39).
Interventions: Not applicable.
Main Outcome Measures: All individuals wore an accelerometer around the waist during waking hours for 7 days. We compared demographic, clinical data, and PA levels between groups using independent samples *t* tests and compared the proportions of those meeting the PA guideline cutoff (150min/wk) using a chi-square test. Additionally, we examined correlates of mean daily MVPA using linear regression in both groups.
Results: Individuals with FAIS spent less time in MVPA (controls, 52.1±25.6min/d; FAIS, 26.9±19.1min/d; *P*=.001) and took fewer steps (controls, 8428±2931 steps/d; FAIS, 6449±2527 steps/d; *P*=.033) than uninjured controls. A lower proportion of individuals with FAIS met the PA cutoff (40.0%) compared with uninjured controls (78.6%; *P*=.020). Higher body mass index (BMI) values and lower (worse) Hip Disability and Osteoarthritis Outcome Score (HOOS)—Quality of Life subscale scores were associated with lower mean daily MVPA in those with FAIS (R^2=21.2%, *P*=.021; R^2=22.0%, *P*=.018; respectively) but not in uninjured controls.
Conclusions: Individuals with FAIS spent less time in daily MVPA, took fewer daily steps, and met recommended PA guideline cutoffs at lower proportions compared with uninjured controls. Higher BMI and lower HOOS-Quality of Life scores were associated with lower mean daily MVPA. Interventions should be developed for individuals with FAIS to increase PA engagement to potentially lessen the risk of future comorbidities associated with decreased PA and increased BMI.

Femoroacetabular impingement syndrome (FAIS) is a hip-related disorder characterized by (1) morphologic abnormalities, affecting the proximal femoral head-neck junction (ie, cam-type), the acetabulum rim (ie, pincer-type), or both (ie, combined-type); (2) clinical signs (eg, limited hip range of motion or positive provocation tests); and (3) patient-reported symptoms (hip pain, tightness, or mechanical symptoms).[1] FAIS presents in young- to middle-aged adults[2,3] and often results in hip pain,[1,4,5] decreased hip-related function and quality of life,[5-7] movement asymmetries/alterations,[7-15] decreased physical activity (PA),[6,16,17] and hip chondropathy.[18-20] In the longer-term, FAIS is associated with the early development of hip osteoarthritis.[21,22] Regarding PA assessment, a recent article recommended the use of objective, device-measured approaches to evaluate function and PA in individuals with hip-related conditions and to determine associations with important patient-centered clinical measures such as pain, function, and/or muscle performance.[23]

To date and to our knowledge, only 3 studies have used a device-measured approach (eg, accelerometers) to evaluate PA levels in individuals with FAIS, either before or after hip arthroscopy.[16,17,24] Specifically, among those with FAIS prior to hip arthroscopy, 1 previous study reported that those with FAIS spent more time participating in very low—intensity PA, spent less time in high-intensity PA, and were more sedentary than controls without FAIS.[17] These early findings provide preliminary evidence that individuals with FAIS may be less active than their peers, and previous research in the general population shows that low levels of PA may increase risks of chronic diseases such as cardiovascular disease and diabetes.[25-29] To maintain physical fitness and health, the American College of Sports Medicine (ACSM) recommends that adults perform at least 150 min/wk of moderate to vigorous physical activity (MVPA).[30] However, we are not aware of any previous studies that have evaluated whether individuals with FAIS meet weekly MVPA recommendations. Furthermore, we currently lack knowledge regarding clinical factors that associate with MVPA in this patient population. Knowing what specific clinical factors are associated with increased participation in PA (such as muscle strength, which is negatively affected in those with FAIS[23]) may provide insights into the future design of PA tailored rehabilitation or clinical interventions. The current study compared device-measured PA levels and the proportions of individuals meeting recommended weekly MVPA cutoffs between individuals with FAIS and uninjured control participants. We hypothesized that individuals with FAIS would spend less time in MVPA and would meet recommended weekly PA cutoffs at lower proportions compared with uninjured control participants. Secondarily, we examined associations between demographic and clinical variables with MVPA levels in both groups.

Methods

Participants

This cross-sectional, comparative study included individuals between the ages of 18 and 49 years with either FAIS or without a history of lower extremity injury or pain (uninjured controls). Individuals with FAIS were recruited from our sports medicine surgeon collaborators (M.K.R., B.A.E, A.M.M.) at Andrews Sports Medicine and Orthopaedic Center and the Department of Orthopaedic Surgery at the University of Alabama at Birmingham who were experienced in examining and treating young- to middle-aged adults with hip pain. Diagnosis of FAIS was based on the FAIS Warwick Agreement,

a recent international diagnostic consensus statement on FAIS.[1] Required findings for an FAIS clinical diagnosis, based on the Warwick Agreement, included (1) patient-reported hip pain or other associated symptoms, (2) at least 1 associated imaging finding (eg, cam or pincer lesion using alpha angle, crossover sign, or center edge angle), and (3) at least 1 associated clinical finding (eg, positive intra-articular provocation tests, decreased or painful hip range of motion).[1] This combination of clinical and imaging findings is the current criterion standard in diagnosing FAIS.[1] Exclusion criteria for the FAIS group included (1) early hip osteoarthritis (Tönnis grade >1),[31] (2) diagnosis of osteopenia or osteoporosis, or (3) previous hip arthroscopy or other lower extremity/spine surgery. Uninjured control participants reported no history of hip-related pain, major lower extremity injury (excluding <3 ankle sprains), or lower extremity/spine surgery and were recruited from the local community via flyers or recommendations from participants with FAIS. Consistent with prior studies, participants with and without FAIS were required to engage in purposeful exercise-related activity for more than 50 hours per year (or up until hip pain onset for participants with FAIS).[32-34] All participants provided written, informed consent prior to participating in the study. Ethical approval for the study protocol was obtained from the University of Alabama at Birmingham Institutional Review Board prior to the beginning of the study (No.: 300001355). After inclusion, we collected demographic data including age, sex, symptom duration (FAIS group only), and body mass index (BMI).

Device-measured PA assessment (FAIS and controls)

To measure daily PA, we provided all participants (FAIS and controls) an accelerometer[35,36] to wear for a 7-day consecutive period (after the onsite testing session). This accelerometer contains a triaxial, digital accelerometer that produces an electric signal proportionate to the force acting on it during movement, and motion outside of normal human movement is band-pass filtered.37 This signal is then converted into activity counts in preset sampling intervals (ie, epochs; 1-minute epochs for this study).[37] The activity counts represent a quantitative measure of activity over time and are linearly associated with the intensity of PA during a period of time. We instructed participants to wear the accelerometer on an elastic belt worn around the waist and above the nonpainful hip (FAIS) or nondominant hip (controls) throughout the entire day for the 7-day period.[16,17]

Data were downloaded from the accelerometers, cleaned, excluding spurious data, and then minute-by-minute activity counts were calculated.[37,38] We excluded data from a given day when a participant's wear time was <480 minutes[39] and excluded all PA data from a participant when the accelerometer was not worn ≥480 min/d on at least 4 days.[37,39] Our primary PA variables of interests included mean daily time spent in (1) light PA (100-1951 activity counts/min),[40] (2) MVPA (≥1952 activity counts/min),[40] and (3) sedentary behavior (<100 activity counts/min)[40] using count cut points developed in healthy adults without FAIS.[40,41] We calculated mean daily step counts from the accelerometers. Scores from accelerometers with similar methods to measure daily PA in adults in free living have provided a reliable[39] and valid measures of energy expenditure.[42] To define recommended weekly PA cut-offs in this study, we adapted the ACSM guidelines of 150 minutes of weekly MVPA to represent a mean daily volume (150min/wk≥21.4min/d).[43]

Patient-reported measures of pain and function (FAIS and controls)

All participants completed the numeric pain rating scale (NPRS)[44,45] to measure hip pain as well as the International Hip Outcome Tool (iHOT-12)[46,47] and the Hip Disability and Osteoarthritis Outcome Score (HOOS)[48,49] to measure hip-related function. The NPRS was used to measure pain intensity (average pain range, 0-10 in whole numbers; 0=no pain and 10=extreme/worst possible pain).[44] The NPRS is valid, reliable, and responsive to change in patients with musculoskeletal pain.[50,51] The iHOT-12 was designed for young, active individuals with hip pathology and involves 12 questions across 4 domains, including symptoms and functional limitations as well as sport, job-related, social, emotional, and lifestyle concerns (0-100 score; 100 representing highest function).[46] The iHOT-12 has been shown to be valid and reliable in individuals with FAIS.[46,52] Lastly, the HOOS includes 5 subscales related to hip function including symptoms, pain, activities of daily living, sport and recreation, and quality of life (each subscale scored independently; 0-100 score; 100 representing a highest function).[48] The HOOS has been shown to be valid and reliable in measuring hip function in individuals with intra-articular hip pain, including those with FAIS.[53]

Hip and thigh muscle strength testing (FAIS and controls)

In all participants, we used an isokinetic dynamometer to evaluate isometric hip and thigh muscle strength, including the knee flexors and extensors and the hip flexors, extensors, and abductors. To evaluate knee flexor and extensor strength, participants were seated with their trunk supported, hips flexed to 90°, the testing knee flexed to 60°, and straps securing the distal femur of the limb being tested as well as across the trunk and waist to minimize compensatory movements during testing.[32,54,55] To evaluate hip flexor and extensor strength, participants were positioned lying supine on the chair, with the chair inclined to 15°.[56,57] The dynamometer axis was aligned with the greater trochanter, and the tested hip was flexed to 45°.[56-58] Lastly, to evaluate hip abductor strength, participants were positioned sideling on a flat dynamometer chair, with the anterior superior iliac spine aligned with the dynamometer axis and the hip positioned at 10° of abduction.[58]

Participants performed 2 practice trials (for each muscle group being tested) followed by 3 maximal 5-second isometric trials, with a 30-second rest break between each trial.[58] We provided verbal encouragement for each trial.[56,57] Use of similar methods to evaluate hip and thigh muscle strength is reliable and able to differentiate muscle strength deficits between injured/painful and uninjured/nonpainful limbs.[58-61] Our variables of interests for each muscle group included the peak torque value (normalized to body mass; Nm/kg) and a limb symmetry index (involved limb value/uninvolved limb value/100%) value.

Table 1 Demographic data for Participants With FAIS and Controls

Variable	FAIS Group (n=25)	Control Group (n=14)	*P* Value*
Age at testing visit (y), mean ± SD (range)	31.0±9.2 (18.8-46.0)	28.1±9.1 (20.4-50.4)	.341
Sex distribution, n (%)			.792
Female	15 (60)	9 (64)	
Male	10 (40)	5 (36)	
BMI at testing visit, mean ± SD	26.1±4.7	26.3±3.4	.899
FAIS subtype, n (%)		—	—
Cam	13 (52)		
Pincer	4 (16)		
Combined	8 (32)		
Symptom duration (y), mean ± SD	4.7±7.1	—	—
Accelerometer wear time (daily min), mean ± SD ~Valid data: ≥8 h/d, and ≥4 d.	824.3±71.5	836.7±57.3	.581

NOTE. BMI calculated as weight in kilograms divided by height in meters squared.
* *P* value is from independent 2-sample *t* test for continuous data or Pearson χ^2 test for categorical data.

Statistical analyses

We compared demographic data between participants with FAIS and uninjured control participants using independent samples *t* tests (age, BMI, muscle strength) and a Pearson chi-square test (sex distribution). Additionally, we compared continuous PA variables of interest (mean daily time spent in light PA, MVPA, and sedentary behavior; mean daily step counts) between participants with FAIS and control participants using independent samples *t* tests. We further compared the proportions of FAIS participants and control participants that met the weekly MVPA guideline cutoff (ACSM; 150min/wk≥21.4min/d) using a Pearson chi-square test. Lastly, in both groups, we used univariable linear regression models to examine demographic (age, sex, BMI) and clinical (symptom duration, iHOT-12, HOOS, NPRS, muscle strength variables of interest) correlates of mean daily MVPA. We defined statistical significance a priori as $P<.05$.

Results

Demographic data for the FAIS and control groups are shown in table 1. The FAIS group and uninjured control group did not differ in age, BMI, sex distribution, or accelerometer wear time (see table 1).

PA data group comparisons

Data on PA per groups are shown in table 2. Compared with the uninjured control group, the FAIS group spent significantly less time in mean daily MVPA and took fewer daily steps. The groups did not differ in mean daily time spent in light PA or sedentary behavior. A significantly lower proportion of the FAIS group met the recommended weekly MVPA cutoff compared with the control group without FAIS (table 2).

Predictors of MVPA

Among participants with FAIS, higher BMI values were associated with lower mean daily MVPA (R^2=21.2%; P=.021) (fig 1A). Additionally, in the FAIS group, lower (worse) HOOS—Quality of Life subscale scores were associated with lower mean daily MVPA (R^2=22.0%; P=.018) (fig 1B). No other demographic (age, sex) or clinical (iHOT-12, other HOOS subscales, NPRS, muscle strength) measures were associated with mean daily MVPA in participants with FAIS (all $P>.05$). In the uninjured control group, there were no significant associations between demographic (age, sex, BMI) or clinical (iHOT-12, other HOOS subscales, NPRS, muscle strength) measures and mean daily MVPA (all $P>.05$).

Discussion

The current study observed that individuals with FAIS spent less per day in MVPA, took fewer steps per day, and were less likely to meet recommended weekly cutoffs for MVPA. Additionally, we observed that higher BMI values and lower HOOS—Quality of Life subscale scores were associated with lower

Table 2 Physical activity data comparisons between groups

Variable	FAIS Group (n=25)	Control Group (n=14)	*P* Value*
Light PA (daily min), mean ± SD	284.9±71.1	267.8±83.1	.501
MVPA (daily min), mean ± SD	26.9±19.1	52.1±25.6	.001†
Sedentary behavior (daily min), mean ± SD	512.4±81.5	516.8±64.3	.864
Steps (daily counts), mean ± SD	6449±2527	8428±2931	.033†
Proportion meeting ACSM weekly MVPA cutoff, n (%)	10 (40)	11 (78.6)	.020†

* *P* value is from independent 2-sample *t* test for continuous data or Pearson χ^2 test for categorical data.
† $P<.05$.

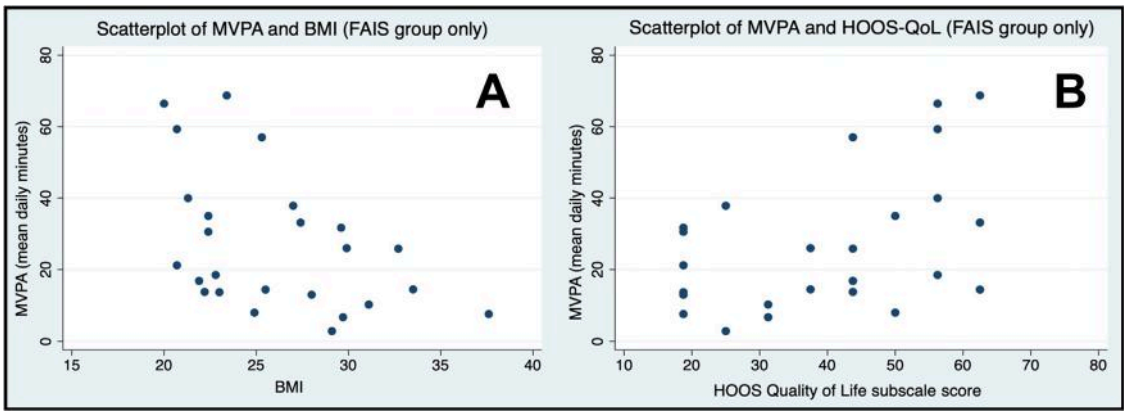

Fig 1 Scatterplots of MVPA vs BMI (A) and MVPA vs HOOS-QoL (B).
NOTE. BMI calculated as weight in kilograms divided by height in meters squared.
Abbreviation: QoL, Quality of Life subscale score.

MVPA in individuals with FAIS. To our knowledge, this is the first study to use a device-measured approach (eg, accelerometers) to determine the proportions of individuals with FAIS meeting recommended weekly MVPA cutoffs compared with uninjured control participants and to examine correlates of MVPA.

Previous studies have documented step count data in individuals with FAIS, either before or after hip arthroscopy, using device-measured techniques.[16,17,24] Even though individuals with FAIS report functional activity limitations (known to correlate with higher pain and altered movement),[62] none of these 3 previous studies[16,17,24] reported significant differences in daily step counts between individuals with FAIS and controls without FAIS (either before[17,24] or 1 year after hip arthroscopy[16]). In the first study, Harris-Hayes et al used a StepWatch, an ankle-worn device, to evaluate total daily strides over 7 days in individuals with FAIS before hip arthroscopy (N=74).[24] In this study, there were no significant differences in total daily strides between those with FAIS and controls without FAIS prior to hip arthroscopy.[24] The second study used a thigh-worn accelerometer to evaluate step counts over 5 days in individuals with FAIS, both before and 1 year after hip arthroscopy (N=41).[16] In this study, daily step counts did not change over the 1 year after hip arthroscopy in individuals with FAIS and did not differ compared with controls without FAIS 1 year after hip arthroscopy.[16] Lastly, a recent cross-sectional study (same cohort as the 2019 prospective study referenced above)[16] used a thigh-worn accelerometer to evaluate daily step counts in individuals with FAIS prior to hip arthroscopy (N=55).[17] In this study, there were no significant differences in daily step counts between individuals with FAIS and controls without FAIS prior to hip arthroscopy.[17]

In contrast to the findings from those previous studies,[16,17,24] our current study showed that those with FAIS took fewer mean daily steps (on average ~2000 fewer steps/d) than our uninjured control sample. Several methodology-related factors could explain the inconsistency between the findings of those previous studies compared with our results. First, 2 of these previous studies[16,17] had participants wear the accelerometers only over a 5-day period. However, in the current study, we monitored PA behavior over a more extended time (7 days) that captured both weekdays and weekends, potentially allowing us to better capture true group differences in walking volume. Second, our sample of participants with FAIS and controls was very similar regarding demographic variables (no significant differences between groups in age, sex distribution, or BMI) and self-reported general exercise history (controls at least 50 h/y currently; FAIS at least 50 h/y currently or until pain symptom onset).[32-34] In contrast, earlier work included participants with FAIS and controls with different ages and BMI values and unknown general exercise history, which may have affected differences in steps between groups.[17,24]

Efforts are needed to evaluate and monitor PA engagement across various intensities in individuals with FAIS, both before and after hip arthroscopy, because it may be a key indicator of recovery and/or reduce future risks of diseases/comorbidities. In our current study and previous relevant work[16,17,24], both individuals with FAIS and control participants performed similar volumes of light PA[16,17,24] and sedentary behavior.[16,24] Only 1 previous study has reported that those with FAIS were more sedentary than controls without FAIS prior to hip arthroscopy.[17] Regarding MVPA, our findings are consistent with the findings of 2 previous studies in individuals with FAIS[16,17] but are inconsistent with another.[24] We found that those with FAIS spent less time in MVPA than uninjured control participants (controls, 52.1±25.6min/d; FAIS, 26.9±19.1min/d) and that a lower proportions met recommended weekly MVPA cutoffs from the ACSM. Similarly, in previous work, those with FAIS performed less bicycling and running (high-activity categories), both before[16,17] and 1 year after hip arthroscopy,[16] than control participants. In the current study, we found that only 40% of participants with FAIS met the recommended weekly MVPA cutoffs. Previous research has shown that between approximately 58%-77% of the general population of adults meet recommended weekly MVPA cutoffs,[63] notably higher than our cohort of participants with FAIS. In the clinical population, a previous study found that 41% and 58% of patients with knee and hip osteoarthritis, respectively, met recommended MVPA cutoffs.[64] Overall, a significant reduction in MVPA in those with FAIS seems to be a commonly reported occurrence in the present literature,[16,17] which may be because of pain

provocation during high-intensity activity and/or fear of pain with PA engagement. In light of this, engagement in MVPA could be a key outcome when treating patients with FAIS, either before or in recovery after hip arthroscopy.

Clinical and rehabilitation-specific factors may affect participation and engagement in PA in individuals with FAIS and could be targeted with relevant interventions. In the current study, we found that higher BMI was associated with lower mean daily MVPA in participants with FAIS, with BMI explaining approximately 21% of the variance in MVPA. Similarly, in previous work in patients after hip or knee arthroplasty, higher BMI was associated with lower levels of PA, measured via step counts (pedometer).[65,66] In addition to BMI, we found that lower HOOS—Quality of Life subscale scores were associated with lower MVPA in participants with FAIS, explaining approximately 22% of the variance in MVPA. We did not find similar associations within our uninjured control participants. Previous work in older adults with end-stage hip and knee osteoarthritis similarly found that higher/better HOOS (hip patients) and Knee Injury and Osteoarthritis Outcome Score (knee patients) Quality of Life subscale scores were associated with higher PA volume, measured as overall activity daily counts.[67] A recent study by Davis-Wilson et al also found that in younger patients after anterior cruciate ligament reconstruction,[68] higher Knee Injury and Osteoarthritis Outcome Score Quality of Life subscale scores were associated with greater MVPA in those with continued knee-related symptoms. Because of the cross-sectional design of our study, directionality of the associations between BMI and MVPA and HOOS—Quality of Life and MVPA are unclear. For example, it is unclear if select individuals with FAIS have higher BMI because of a reduction PA, with their reduced PA engagement being caused by another factor, such as hip pain. In the same vein, it is unclear if quality of life scores are lower because of reduced PA engagement/participation or if hip-related pain or symptoms are dually contributing to both reduced HOOS—Quality of Life scores and reduced PA.

Study limitations

The current study has several strengths and limitations that should be recognized. A strength of our study was that we determined the proportions of those with FAIS meeting recommended weekly MVPA cutoffs using an objective, device-measured approach and compared those proportions with uninjured control participants. Knowledge about the proportions of individuals with FAIS meeting recommended weekly MVPA cutoffs could lead to the development of tailored PA promotion programs, with an overall goal of increasing activity engagement in this patient population. The second strength of our study was that we performed regression analyses to help provide greater insight into clinically relevant factors (pain, function, and muscle strength) associated with MVPA. A first limitation of the current study is that we enrolled a relatively small sample size (FAIS and controls) compared with previous relevant studies.[16,17,24] Second, the current study lacks longitudinal data to examine the effect of clinical and rehabilitation-specific factors (pain, function, muscle strength) on future PA levels. To our knowledge, no previous studies have examined associations between measures of PA and potential rehabilitation targets. Future research is needed in larger samples with FAIS to examine modifiable clinical factors associated with changes in PA levels over time, the intersection between PA and hip-related function, and longitudinal trajectories of PA engagement and healthy weight in those with FAIS who undergo or forego hip arthroscopy.

Conclusions

In the current study, individuals with FAIS spent less time in MVPA, took fewer mean daily steps, and met recommended weekly MVPA cutoffs at lower proportions compared with uninjured controls. Among FAIS group, higher BMI values and lower HOOS—Quality of Life subscale scores were associated with lower mean daily MVPA. Future research should evaluate the effectiveness of PA promotion strategies in individuals with FAIS to avoid potential risk future for health-related comorbidities/diseases associated with decreased PA.

Corresponding author

Matthew Ithurburn, PT, DPT, PhD, 833 St. Vincent's Dr, Suite 205, Birmingham, AL, 35205. *E-mail address:* matti@asmi.org.

References

1. Griffin DR, Dickenson EJ, O'Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. Br J Sports Med 2016;50:1169–76.
2. Clohisy JC, Baca G, Beaule PE, et al. Descriptive epidemiology of femoroacetabular impingement: a North American cohort of patients undergoing surgery. Am J Sports Med 2013;41:1348–56.
3. Reiman MP, Agricola R, Kemp JL, et al. Consensus recommendations on the classification, definition and diagnostic criteria of hip-related pain in young and middle-aged active adults from the International Hip-related Pain Research Network, Zurich 2018. Br J Sports Med 2020;54:631–41.
4. Thorborg K, Kraemer O, Madsen AD, Holmich P. Patient-reported outcomes within the first year after hip arthroscopy and rehabilitation for femoroacetabular impingement and/or labral injury: the difference between getting better and getting back to normal. Am J Sports Med 2018;46:2607–14.
5. Rylander JH, Shu B, Andriacchi TP, Safran MR. Preoperative and postoperative sagittal plane hip kinematics in patients with femoroacetabular impingement during level walking. Am J Sports Med 2011;39(Suppl):36s–42s.
6. Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS. Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. Br J Sports Med 2015;49:230–42.
7. Bagwell JJ, Snibbe J, Gerhardt M, Powers CM. Hip kinematics and kinetics in persons with and without cam femoroacetabular impingement during a deep squat task. Clin Biomech (Bristol, Avon) 2016;31:87–92.
8. Samaan MA, Schwaiger BJ, Gallo MC, et al. Joint loading in the sagittal plane during gait is associated with hip joint abnormalities in patients with femoroacetabular impingement. Am J Sports Med 2017;45:810–8.
9. Kennedy MJ, Lamontagne M, Beaule PE. Femoroacetabular impingement alters hip and pelvic biomechanics during gait walking biomechanics of FAI. Gait Posture 2009;30:41–4.

10. Lamontagne M, Kennedy MJ, Beaule PE. The effect of cam FAI on hip and pelvic motion during maximum squat. Clin Orthop Relat Res 2009;467:645–50.
11. Hunt MA, Guenther JR, Gilbart MK. Kinematic and kinetic differences during walking in patients with and without symptomatic femoroacetabular impingement. Clin Biomech (Bristol, Avon) 2013;28:519–23.
12. Farkas GJ, Cvetanovich GL, Rajan KB, Espinoza Orias AA, Nho SJ. Impact of femoroacetabular impingement morphology on gait assessment in symptomatic patients. Sports Health 2015;7:429–36.
13. Diamond LE, Wrigley TV, Bennell KL, et al. Hip joint biomechanics during gait in people with and without symptomatic femoroacetabular impingement. Gait Posture 2016;43:198–203.
14. Diamond LE, Bennell KL, Wrigley TV, Hinman RS, O'Donnell J, Hodges PW. Squatting biomechanics in individuals with symptomatic femoroacetabular impingement. Med Sci Sports Exerc 2017;49:1520–9.
15. Malloy P, Neumann DA, Kipp K. Hip biomechanics during a single-leg squat: five key differences between people with femoroacetabular impingement syndrome and those without hip pain. J Orthop Sports Phys Ther 2019;49:908–16.
16. Kierkegaard S, Dalgas U, Lund B, Lipperts M, Soballe K, Mechlenburg I. Despite patient-reported outcomes improve, patients with femoroacetabular impingement syndrome do not increase their objectively measured sport and physical activity level 1 year after hip arthroscopic surgery. Results from the HAFAI cohort. Knee Surg Sports Traumatol Arthrosc 2019;47:488–500.
17. Reimer LCU, Kierkegaard S, Mechlenburg I, Jacobsen JS. Does daily physical activity differ between patients with femoroacetabular impingement syndrome and patients with hip dysplasia? A cross-sectional study in 157 patients and 60 healthy volunteers. Int J Sports Phys Ther 2021;16:1084–92.
18. Kemp JL, Makdissi M, Schache AG, Pritchard MG, Pollard TC, Crossley KM. Hip chondropathy at arthroscopy: prevalence and relationship to labral pathology, femoroacetabular impingement and patient-reported outcomes. Br J Sports Med 2014;48:1102–7.
19. Nepple JJ, Goljan P, Briggs KK, Garvey SE, Ryan M, Philippon MJ. hip strength deficits in patients with symptomatic femoroacetabular impingement and labral tears. Arthroscopy 2015;31:2106–11.
20. Grace T, Samaan MA, Souza RB, Link TM, Majumdar S, Zhang AL. Correlation of patient symptoms with labral and articular cartilage damage in femoroacetabular impingement. Orthop J Sports Med 2018;6:2325967118778785.
21. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br 2005;87:1012–8.
22. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res 2003: 112–20.
23. Mosler AB, Kemp J, King M, et al. Standardised measurement of physical capacity in young and middle-aged active adults with hip-related pain: recommendations from the first International Hip-related Pain Research Network (IHiPRN) meeting, Zurich, 2018. Br J Sports Med 2020;54:702–10.
24. Harris-Hayes M, Steger-May K, Pashos G, Clohisy JC, Prather H. Stride activity level in young and middle-aged adults with hip disorders. Physiother Theory Pract 2012;28:333–43.
25. Li J, Siegrist J. Physical activity and risk of cardiovascular disease—a meta-analysis of prospective cohort studies. Int J Environ Res Public Health 2012;9:391–407.
26. Sluik D, Buijsse B, Muckelbauer R, et al. Physical activity and mortality in individuals with diabetes mellitus: a prospective study and meta-analysis. Arch Intern Med 2012;172:1285–95.
27. Wilmot EG, Edwardson CL, Achana FA, et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia 2012;55:2895–905.
28. Biswas A, Oh PI, Faulkner GE, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. Ann Intern Med 2015;162:123–32.
29. Moore SC, Lee IM, Weiderpass E, et al. Association of leisure-time physical activity with risk of 26 types of cancer in 1.44 million adults. JAMA Intern Med 2016;176:816–25.
30. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 2011;43:1334–59.
31. Clohisy JC, Carlisle JC, Trousdale R, et al. Radiographic evaluation of the hip has limited reliability. Clin Orthop Relat Res 2009;467:666–75.
32. Ithurburn MP, Paterno MV, Ford KR, Hewett TE, Schmitt LC. Young athletes with quadriceps femoris strength asymmetry at return to sport after anterior cruciate ligament reconstruction demonstrate asymmetric single-leg drop-landing mechanics. Am J Sports Med 2015;43:2727–37.
33. Ithurburn MP, Paljieg A, Thomas S, Hewett TE, Paterno MV, Schmitt LC. Strength and function across maturational levels in young athletes at the time of return to sport after ACL reconstruction. Sports Health 2019;11:324–31.
34. Ithurburn MP, Paterno MV, Thomas S, et al. Clinical measures associated with knee function over two years in young athletes after ACL reconstruction. Knee 2019;26:355–63.
35. Vanhelst J, Mikulovic J, Bui-Xuan G, et al. Comparison of two ActiGraph accelerometer generations in the assessment of physical activity in free living conditions. BMC Res Notes 2012;5:187.
36. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. J Sci Med Sport 2011;14:411–6.
37. Ezeugwu V, Klaren RE, Hubbard EA, Manns PT, Motl RW. Mobility disability and the pattern of accelerometer-derived sedentary and physical activity behaviors in people with multiple sclerosis. Prev Med Rep 2015;2:241–6.
38. Sandroff BM, Motl RW, Suh Y. Accelerometer output and its association with energy expenditure in persons with multiple sclerosis. J Rehabil Res Dev 2012;49:467–75.
39. Aadland E, Ylvisaker E. Reliability of the Actigraph GT3X+ accelerometer in adults under free-living conditions. PLoS One 2015;10:e0134606.
40. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. Med Sci Sports Exerc 1998;30:777–81.
41. Matthew CE. Calibration of accelerometer output for adults. Med Sci Sports Exerc 2005;37(11 Suppl):S512–22.
42. Kelly LA, McMillan DG, Anderson A, Fippinger M, Fillerup G, Rider J. Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. BMC Med Phys 2013;13:5.
43. Piercy KL, Troiano RP. Physical activity guidelines for Americans from the US Department of Health and Human Services. Circ Cardiovasc Qual Outcomes 2018;11:e005263.
44. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: visual analog scale for pain (VAS Pain), numeric rating scale for pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res (Hoboken) 2011;63(Suppl 11): S240–52.

45. Jensen MP, McFarland CA. Increasing the reliability and validity of pain intensity measurement in chronic pain patients. Pain 1993;55:195–203.
46. Griffin DR, Parsons N, Mohtadi NG, Safran MR. Multicenter Arthroscopy of the Hip Outcomes Research Network. A short version of the International Hip Outcome Tool (iHOT-12) for use in routine clinical practice. Arthroscopy 2012;28:611–6. [quiz: 616-8].
47. Ramisetty N, Kwon Y, Mohtadi N. Patient-reported outcome measures for hip preservation surgery-a systematic review of the literature. J Hip Preserv Surg 2015;2:15–27.
48. Nilsdotter A, Bremander A. Measures of hip function and symptoms: Harris Hip Score (HHS), Hip Disability and Osteoarthritis Outcome Score (HOOS), Oxford Hip Score (OHS), Lequesne Index of Severity for Osteoarthritis of the Hip (LISOH), and American Academy of Orthopedic Surgeons (AAOS) Hip and Knee Questionnaire. Arthritis Care Res (Hoboken) 2011;63(Suppl 11):S200–7.
49. Klassbo M, Larsson E, Mannevik E. Hip Disability and Osteoarthritis Outcome Score. An extension of the Western Ontario and McMaster Universities Osteoarthritis Index. Scand J Rheumatol 2003;32:46–51.
50. Farrar JT, Young Jr JP, LaMoreaux L, Werth JL, Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain 2001;94:149–58.
51. Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. Eur J Pain 2004;8:283–91.
52. Thorborg K, Tijssen M, Habets B, et al. Patient-reported outcome (PRO) questionnaires for young to middle-aged adults with hip and groin disability: a systematic review of the clinimetric evidence. Br J Sports Med 2015;49:812.
53. Kemp JL, Collins NJ, Roos EM, Crossley KM. Psychometric properties of patient-reported outcome measures for hip arthroscopic surgery. Am J Sports Med 2013;41:2065–73.
54. Schmitt LC, Paterno MV, Hewett TE. The impact of quadriceps femoris strength asymmetry on functional performance at return to sport following anterior cruciate ligament reconstruction. J Orthop Sports Phys Ther 2012;42:750–9.
55. Schmitt LC, Paterno MV, Ford KR, Myer GD, Hewett TE. Strength asymmetry and landing mechanics at return to sport after anterior cruciate ligament reconstruction. Med Sci Sports Exerc 2015;47:1426–34.
56. Casartelli NC, Maffiuletti NA, Item-Glatthorn JF, et al. Hip muscle weakness in patients with symptomatic femoroacetabular impingement. Osteoarthritis Cartilage 2011;19:816–21.
57. Kierkegaard S, Mechlenburg I, Lund B, Soballe K, Dalgas U. Impaired hip muscle strength in patients with femoroacetabular impingement syndrome. J Sci Med Sport 2017;20:1062–7.
58. Meyer C, Corten K, Wesseling M, et al. Test-retest reliability of innovated strength tests for hip muscles. PLoS One 2013;8: e81149.
59. Fitzgerald GK, Piva SR, Irrgang JJ. A modified neuromuscular electrical stimulation protocol for quadriceps strength training following anterior cruciate ligament reconstruction. J Orthop Sports Phys Ther 2003;33:492–501.
60. Krishnan C, Williams GN. Factors explaining chronic knee extensor strength deficits after ACL reconstruction. J Orthop Res 2011;29:633–40.
61. Lewek M, Rudolph K, Axe M, Snyder-Mackler L. The effect of insufficient quadriceps strength on gait after anterior cruciate ligament reconstruction. Clin Biomech (Bristol, Avon) 2002;17:56–63.
62. Alrashdi NZ, Brown-Taylor L, Bell MM, Ithurburn MP. Movement patterns and their associations with pain, function, and hip morphology in individuals with femoroacetabular impingement syndrome: a scoping review. Phys Ther 2021;101:pzab185.
63. Zenko Z, Willis EA, White DA. Proportion of adults meeting the 2018 Physical Activity Guidelines for Americans According to Accelerometers. Front Public Health 2019;7:135.
64. Wallis JA, Webster KE, Levinger P, Taylor NF. What proportion of people with hip and knee osteoarthritis meet physical activity guidelines? A systematic review and meta-analysis. Osteoarthritis Cartilage 2013;21:1648–59.
65. McClung CD, Zahiri CA, Higa JK, Amstutz HC, Schmalzried TP. Relationship between body mass index and activity in hip or knee arthroplasty patients. J Orthop Res 2000;18:35–9.
66. Sechriest 2nd VF, Kyle RF, Marek DJ, Spates JD, Saleh KJ, Kuskowski M. Activity level in young patients with primary total hip arthroplasty: a 5-year minimum follow-up. J Arthroplasty 2007;22:39–47.
67. Leichtenberg CS, van Tol FR, Gademan MGJ, et al. Are pain, functional limitations and quality of life associated with objectively measured physical activity in patients with end-stage osteoarthritis of the hip or knee? Knee 2021;29:78–85.
68. Davis-Wilson HC, Thoma LM, Longobardi L, et al. Quality of life associates with moderate to vigorous physical activity following anterior cruciate ligament reconstruction. J Athl Train 2022;57:532–9.