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Stride Activity Level in Young and Middle-aged Adults with Hip Disorders

Marcie Harris-Hayes, PT, DPT, MSCI, OCS¹, Karen Steger-May, MA² [Research Statistician], Gail Pashos, BS³ [Research Coordinator], John C. Clohisey, MD⁴ [Professor], and Heidi Prather, DO, MD⁵ [Associate Professor]

²Division of Biostatistics, Washington University School of Medicine, 660 South Euclid Avenue, Box 8067, St. Louis, MO. 63110, karens@wubios.wustl.edu

³Department of Orthopaedic Surgery, Washington University School of Medicine, 660 South Euclid Avenue, Box 8233, St. Louis, MO. 63110, pashosg@wudosis.wustl.edu

⁴Department of Orthopaedic Surgery, Washington University School of Medicine, 660 South Euclid Avenue, Box 8233, St. Louis, MO. 63110, clohisyj@wudosis.wustl.edu

⁵Department of Orthopaedic Surgery, Washington University School of Medicine, 660 South Euclid Avenue, Box 8233, St. Louis, MO. 63110, pratherh@wudosis.wustl.edu

Abstract

Objectives—To determine the activity level, represented by total daily strides (TDS), of young and middle-aged adults with hip disorders and asymptomatic controls and to assess the association between TDS and self-report functional measures.

Methods—Patients (age 15–50) with deep hip or groin pain (n=202) and controls (n=20) wore an accelerometer that recorded TDS. Symptomatic subjects completed self-report questionnaires. Symptomatic subjects were classified into subgroups: femoroacetabular impingement (FAI), developmental hip dysplasia (DDH), isolated labral tear (LT) and osteoarthritis (OA) based on intraoperative findings. Between-group comparisons of TDS were performed and correlations between TDS and questionnaires were determined.

Results—Overall, controls recorded greater TDS than symptomatic subjects, however between-group comparisons showed FAI and DDH were similar to controls. OA demonstrated fewer TDS than FAI (4327 [2075] vs. 5095 [2354]). In symptomatic subjects, TDS had a low correlation with modified Harris Hip Score ($r=0.33$) and the UCLA ($\rho = 0.30$), but no correlation with the Marx.

Conclusions—Subjects with hip disorders demonstrate reduced TDS compared to controls, however some subgroups demonstrated TDS similar to controls. In addition, symptomatic subjects demonstrated relatively high TDS while reporting poor function. Accelerometers can be used in clinical populations to provide additional information about activity not represented by traditional functional measures.

Keywords

activity monitor; accelerometer; hip pain; Harris Hip Score; physical activity

¹Corresponding Author: Marcie Harris-Hayes, PT, DPT, MSCI, OCS, is Assistant Professor, Program in Physical Therapy, Washington University Medical School, Campus Box 8502, St. Louis, MO 63108. Phone: 314-286-1435; Fax: 314-286-1410; harrisma@wustl.edu.

DECLARATION OF INTEREST

Each author certifies that he or she has no commercial associations that might pose a conflict of interest in connection with the submitted article.

INTRODUCTION

Clinical investigation of hip pain is challenging due to variability in the patient population and diversity of disorders such as femoroacetabular impingement (FAI), developmental dysplasia of the hip (DDH), labral tears (LT), and secondary osteoarthritis (OA). Adding to the complexity of clinical investigation of hip pain are the multiple factors proposed to contribute to these hip disorders. Proposed risk factors that have been described include trauma, (Tepper and Hochberg 1993; Burnett et al 2006) genetics, (Spencer et al 2005; Pollard et al 2010; Wynne-Davies 1970) sex (Hack et al 2010; Gosvig et al 2010; Tepper and Hochberg 1993) and bony abnormalities. (Klaue, Durnin and Ganz 1991; Ganz et al 2003; Beck et al 2005; Guevara et al 2006) Another factor to consider is physical activity level and its relationship to hip disorders.

Many reports suggest that bony abnormalities, such as those found in FAI and DDH, are associated with hip pain. (Burnett et al 2006; Langlais et al 2006; Gosvig et al 2010) Femoroacetabular impingement occurs when the femoral neck prematurely abuts against the acetabular rim during hip motion due to either acetabular over-coverage of the femur or a loss of the concavity of the femoral head-neck junction. (Maheshwari, Malik and Dorr 2007; Notzli et al 2002; Ganz et al 2003) In acetabular dysplasia, a shallow acetabulum results in a smaller weightbearing surface and thus increased contact stresses that may contribute to damage to the acetabular labrum and articular surfaces. (Klaue, Durnin and Ganz 1991; Mavcic et al 2008) Although these bony abnormalities are likely contributors to hip pathology, hip pain may occur in the absence of bony abnormalities, such as in the case of an isolated labral tear. (Burnett et al 2006; Peelle et al 2005) This suggests that other factors must be considered.

Physical activity level has not been studied in adults with non-arthritic hip pain, however may be an important factor to consider. Injury is believed to be related to the amount or dose of physical stress applied to the affected tissues. (Mueller and Maluf 2002) For instance, too little activity or a low dose of physical stress, may lead to atrophy in the musculoskeletal tissues, such as muscle or bone, leaving them less capable to tolerate stresses. (Mueller and Maluf 2002) In addition, too much activity or high dose of physical stress may lead to injury by exceeding the tissue's ability to tolerate the applied stress. High dose stress may come in the form of a high velocity force applied one time, the mechanism in traumatic injury, or in the form of relatively lower forces applied repetitively over time, the proposed mechanism in overuse syndromes. (Mueller and Maluf 2002) The interaction of physical activity level and the associated physical stress combined with other proposed factors, such as bony abnormalities, may place the hip structures at greater risk for injury than the risk posed by one factor alone. Quantitative assessment of an individual's activity level, may provide some insight to the relative level of stress occurring at the joint.

Traditional hip-specific outcome scoring systems to assess functional ability and provide insight to activity level were primarily developed for the less active, elderly patient treated with hip arthroplasty. (Bellamy N et al 1988) More recently, investigators have used modified or new functional measures to evaluate the non-arthritic adult patient population. (Byrd and Jones 2000) All of these measures provide information about the patient's functional ability, however they have certain limitations. In particular, all are patient self-report scores, and none objectively monitor patient activity.

Accelerometers provide a quantitative method to assess activity level by recording the number of strides taken by the person wearing the device. The StepWatch activity monitor (SAM) (Cyma StepWatch,™ Cyma Corporation, Mountlake Terrace, WA, USA) is a small

accelerometer worn while the person performs their regular daily and fitness activities. The SAM has been used to assess activity level in a variety of musculoskeletal disorders.(Silva et al 2002; Daniel et al 2007; Maluf and Mueller 2003; Cavanaugh et al 2007) However, we are unaware of any studies that report the use of accelerometers to quantify activity level in patients with hip disorders prior to surgical intervention.

The purpose of this study was to determine the total daily strides (TDS) of adults, aged 15–50 years with hip disorders and asymptomatic controls. We hypothesized that subjects with hip disorders would demonstrate lower TDS than asymptomatic controls. In addition, we expected differences in TDS among the symptomatic subgroups, including femoroacetabular impingement (FAI),developmental dysplasia of the hip (DDH), isolated acetabular labral tears without bony abnormalities (LT), and osteoarthritis (OA). We expected subjects with OA would demonstrate lower daily strides than the other symptomatic subgroups. Secondly, we assessed the relationship between TDS and self-report functional measures including the modified Harris Hip Score (MHHS),(Byrd and Jones 2000) the University of California Los Angeles activity score (UCLA)(Amstutz et al 1984) and the Marx Activity Rating Scale (Marx).(Marx et al 2001) We expected a positive correlation between TDS measured by the SAM and the functional measures.

METHODS

Subjects

Subjects with hip disorders—Subjects were recruited from the outpatient orthopaedic clinics affiliated with an academic healthcare center. The subjects included in the current report represent a subgroup of an ongoing study in which self-report functional measures are collected on all subjects. All potential subjects were patients who had elected to undergo surgical treatment of hip or groin pain that had not resolved with non-operative management including one or more of the following: nonsteroidal anti-inflammatory drugs, physical therapy or injections. The senior author (JCC), an orthopaedic surgeon who specializes in the young adult hip, evaluated and provided a clinical diagnosis for each patient based on clinical examination and radiographic findings. Patients given the diagnoses of FAI, DDH, LT, and OA were approached by clinic staff to determine interest in participating in the study. Patients interested in participating were screened and enrolled in consecutive fashion. Inclusion criteria for the *ongoing study* included the following: 1) presence of deep hip or groin pain for at least three months, 2) symptom reproduction with the anterior hip impingement test indicating intra-articular source of pain, 3) between the ages of 15–60 years and 4) able to ambulate independently. Exclusions for the *ongoing study* were any major coexisting joint conditions or co-morbidities that limited participation in physical activity. Additional exclusion criteria for the *current report* included 1) the subject's diagnosis was not yet surgically confirmed, 2) the subject received a resurfacing procedure or 3) the subject was older than age 50 at the time of data collection.

Subgroups based on the clinical diagnosis and confirmed intra-operatively were formed and are described in table 1. All subjects provided informed consent in accordance with study procedures approved by the Human Research Protection Office at *blinded*.

Asymptomatic control subjects—Asymptomatic controls were identified by two methods including a convenience sample of family and friends of the enrolled subjects with hip pain and volunteers from the University-based Volunteer for Health recruitment pool. To be included in this study control subjects were between 15 and 50 years old, had no history of hip pain and no coexisting joint conditions or co-morbidities that limited participation in physical activity. Data were collected from the asymptomatic subjects during the same time

frame as subjects with hip pain to control for confounding factors such as seasonal variation or temporal influences that occurred during the study.

Test Procedures

Demographics and Self-Report Questionnaires—Demographic information and medical history were obtained through interview and review of medical records. As part of our standard practice, the subjects with hip pain also completed self-report questionnaires including the MHHS,(Byrd and Jones 2000) the UCLA(Amstutz et al 1984) and the Marx(Marx et al 2001) prior to the physical examination. Asymptomatic controls did not complete these questionnaires.

The MHHS(Byrd and Jones 2000) is a hip-specific functional measure that consists of questions related to the subject's current pain level (44 points) and functional ability (47 points). The MHHS excludes the points allocated in the original Harris Hip score for range of motion and deformity. The points are totaled then multiplied by 1.1 for a total possible score of 100 with higher values indicating a higher level of function.

The UCLA (Amstutz et al 1984) is a sport-specific questionnaire used to assess physical activity level. The UCLA provides descriptive activity levels ranging from 1–10, 1 is defined as wholly inactive and dependent on others and 10 is defined as regularly participates in impact sports such as jogging, tennis, skiing, etc. The subject is instructed to choose the response that best describes their activity level over the last 6 months.

The Marx(Marx et al 2001) estimates the subject's participation in high demand activity levels. The Marx lists four items: running, cutting, decelerating and pivoting. The subject indicates how often they performed each activity in their healthiest and most active state in the past year. Although the Marx was developed as a knee-specific functional measure, the questions appear to be relevant to hip pain.

Stride activity monitoring—The SAM was used to record the daily stride activity of all enrolled subjects. The SAM assesses activity level by recording the number of strides taken in 1 minute intervals for up to 2 months. A stride is defined as heel strike of one foot to the next heel strike of the same foot.(Boenig DD 1977) The SAM is completely sealed so the subject is blinded to their recorded data. The accuracy of the SAM is reported to be as high as 99%.(Shepherd et al 1999; Karabulut, Crouter and Bassett, Jr. 2005; McDonald CM et al 2005)

After subject enrollment, the SAM's sensitivity was programmed to best fit the subject's gait using their height and normal walking speed. Once the SAM was programmed, it was set to continuously record the number of strides per minute. Subjects received standard verbal and written instructions in the proper wear of the SAM. They were instructed to wear the SAM for seven days during waking hours, however they were allowed to remove the device during bathing and sleeping. Subjects with hip pain were instructed to wear the SAM on their painful limb. Controls were instructed to select a limb side and to always wear the SAM on the selected limb. After seven days of wear, the subjects returned the device in a postage-paid mailing package.

Data processing

Stride activity data were generated using StepWatch analysis software and then edited manually. To reduce a bias effect, standard rules to determine inclusion/exclusion criteria for SAM data were applied.(King et al 2011) Each day was evaluated for wear. For a day to be included in the analysis, strides must be recorded a minimum of ten hours within the 24

hour period starting at midnight. If a day's data demonstrated a block of time greater than two hours of no strides recorded, the total time demonstrating recorded strides was determined. If the total time of recorded strides was less than 10 hours, the day was excluded. Examples of days included and excluded are provided in figure 1. A subject's data were included in the final analysis if they demonstrated 4 days of wear, including one weekend day (i.e., Saturday or Sunday). (Silva et al 2005) Standard data points were average total strides taken per day and percent of time at no, low, medium, and high activity defined as less 15, 15–40, 41–75 and greater 75 strides per minute.

Statistical Analysis

For continuous demographic and self-report questionnaire data, between-group comparisons were performed using analysis of variance (ANOVA). When the overall ANOVA was significant ($P < 0.05$), Tukey-adjusted least square means were used to determine which groups were significantly different. Chi-square tests with Bonferroni's correction for all pairwise comparisons were used to assess between-group differences in categorical variables.

The primary analysis was a comparison of TDS across all diagnostic groups. As several days worth of data were collected, data were analyzed using Generalized Estimating Equations (GEEs) to account for the correlation of multiple measurements for each participant. When the overall model was significant ($P < 0.05$), statistical contrasts within the framework of the GEE model were used to perform all pairwise comparisons between groups. An *a priori* statistical contrast was used to determine if there were significant differences between the asymptomatic control group and the average of the symptomatic group. Due to a lack of variability in the percent of time spent at high activity, prior to analysis a median split was performed to categorize subjects as spending more or less time at high activity compared to the median of the overall sample (0.8% of time at high activity).

Pearson (r) or Spearman (ρ) correlation coefficients were calculated to assess the degree of association between self-report questionnaire data and mean TDS for the symptomatic subjects. For these analyses, each participant's total strides were averaged over all days examined.

Due to violations of the assumptions required for the statistical method used, some variables required log or rank transformation prior to analysis (where noted). Data are presented as mean $\pm$ standard deviation. The data analysis was generated using SAS software, version 9.2 of the SAS System for Linux (SAS Institute Inc., Cary, NC, USA).

RESULTS

Study sample selection

A total of 418 subjects were enrolled in the ongoing study. Of these, 113 (27%) did not satisfy inclusion criteria for the current report for the following reasons: diagnosis not yet surgically confirmed ($n=43$), resurfacing surgical procedure ($n=17$), age greater than 50 years ($n=51$), recent injury ($n=1$), and consent withdrawal ($n=1$). Of the remaining 305 eligible subjects, 83 (27%) were excluded for insufficient activity data (i.e., subject did not have 10 hours per day for 4 days including a weekend day).

These 83 excluded subjects (50 female, 33 male) with an average age of 35 years did not differ significantly from the 222 included subjects on gender ($P=0.87$), age ($P=0.82$), BMI ($P=0.50$), MHHS ($P=0.08$), MHHS pain subscale ($P=0.36$), and UCLA ($P=0.70$). The included subjects had significantly higher levels of function compared to the excluded

subjects as measured by the MHHS function subscale (35 (8) versus 32 (10), respectively, $P=0.02$)

Sample characteristics

Table 2 reports demographic characteristics of the 222 subjects included in the current study. One hundred and thirty six females and 86 males with an average age of 36 years (range 15 – 50) were included. The LT subgroup was composed of significantly more females (92%) than the FAI (51%), DDH (62%), and OA subgroups (53%). FAI (31.9 (11)) and DDH (29.1 (7)) subgroups were significantly younger as compared to the asymptomatic controls (40.1 (7)) and OA subgroup (40.9 (8)). The OA subgroup was significantly more overweight (BMI), less functional (MHHS function subscale), and less active (Marx) compared to the FAI and LT subgroups. Average MHHS pain scores were 16–17 and did not differ across symptomatic subgroups ($P=0.89$).

Stride activity data collection

The 222 subjects included contributed a total of 1384 days worth of TDS data. Subjects wore the activity monitors for an average of 23 hours per day (range 20 – 24 hours) for an average of 6 days (range 4 – 10 days) with no differences across groups for average wear time ($P=0.19$) or average number of days with data ($P=0.78$). The activity data were collected, on average 93 days prior to surgery (range 7 to 363 days) and this time differed across subgroups (LT 76 (60), FAI 103 (52), DDH 111 (87), OA 85 (65), $P=0.0004$).

Stride activity measures

There was a wide range of TDS among all of the subgroups (figure 2). Overall, the asymptomatic control group took significantly more strides than the average of the symptomatic group combined ($P=0.04$). Total daily strides differed among groups ($P=0.02$, table 3). The OA subgroup demonstrated significantly fewer daily strides than the FAI subgroup (4327 (2075) vs. 5095 (2354), $P=0.006$) but no other significant differences within the symptomatic subgroups resulted. The asymptomatic controls took significantly more strides than the LT subgroup ($P=0.04$) and OA subgroup ($P=0.004$) but took similar number of strides as the FAI subgroup ($P=0.54$) and DDH subgroup ($P=0.10$).

The proportion of the day spent in no activity ($P=0.10$), low activity ($P=0.10$), medium activity ($P=0.18$), and high activity ($P=0.10$) was similar across groups. The average time spent at each activity level for the overall sample was 74%, 17%, 7%, and 1.2%, respectively. No differences were found when these activity levels were compared for the asymptomatic subjects and the average of the combined symptomatic group.

Both age (Sechriest et al 2007; Silva et al 2002) and BMI (Sechriest et al 2007; McClung et al 2000) have been shown to have a negative correlation with activity level. We therefore performed additional analyses to determine whether an adjustment for these covariates altered the results of the between-group analyses (data not reported). Both age and BMI were significant covariates but overall conclusions for the SAM activity measures were unchanged. However, the original study was not powered to assess the potential role of covariates in the association between activity level and hip disorder.

Self-report measures and stride activity

In the symptomatic subject group overall, we found a positive but low correlation between TDS and total MHHS ($r=0.33$, $P<0.0001$), MHHS Functional subscale ($r=0.34$, $P<0.0001$) and the UCLA ($\rho=0.30$, $P<0.0001$). There was no correlation between TDS and the Marx ($\rho=0.05$, $P=0.49$).

DISCUSSION

The goals of this study were to determine the TDS of adults with various hip disorders and asymptomatic controls, and to assess the relationship between TDS and self-report functional measures. As expected, symptomatic subjects demonstrated fewer strides than asymptomatic subjects. With subgroup comparisons, subjects with OA and LT demonstrated fewer strides than asymptomatic controls. However, subjects with DDH and FAI demonstrated similar stride counts as the asymptomatic controls. Subjects with OA demonstrated fewer strides compared to subjects with FAI. In addition, we found a positive but low correlation between total daily strides and the MHHS and the UCLA. There was no relationship between total daily strides and the Marx.

To our knowledge, this is the first study to report monitored activity level of young and middle-aged adults with hip disorders prior to surgery. Our study provides baseline TDS for asymptomatic subjects and for subjects with FAI, DDH, LT and OA. In addition, we have demonstrated that using the SAM or similar device to objectively monitor activity level provides additional information not represented in the MHHS, UCLA or Marx outcome measures.

Activity level

We found that symptomatic subjects demonstrated fewer strides than our asymptomatic subjects, however we were surprised the symptomatic subjects demonstrated relatively high levels of stride activity while reporting poor function (Harris 1969) on the MHHS. All symptomatic subgroups demonstrated stride counts that meet or approach the often recommended 5000 strides per day (10,000 steps per day) while reporting average MHHS scores ranging from 51–60%.

The high TDS in the symptomatic subgroups may be explained by our sample demographics. Age has been shown to be negatively associated with activity level. (Sechriest et al 2007; Silva et al 2002) Our sample is relatively young (range 15–50), therefore subgroup TDS may be high due to subject age. Within our sample, however age did not appear to affect the findings related to activity level and subgroup. Employment is also associated with higher activity level. (Hirata et al 2006) We did not collect employment status, however our subjects were within the typical working age and therefore employment may be a factor. Another consideration is the Hawthorne effect. (McCarney et al 2007) The individuals in our study knew their activity level was being monitored and, as a result, may have increased their activity level while wearing the monitor. We encouraged all subjects to maintain their normal routine while wearing the device, however recognize that the recorded stride counts may be higher than the subjects' normal routine.

It is important to note the wide range of activity levels within each of the groups. For example, the range within the asymptomatic group (highest stride count) and OA subgroup (lowest stride count) was 1199–12326 strides/day and 648–14132 strides/day, respectively. The variability within groups suggests that assumptions about walking ability cannot be based on structural deformity or degenerative changes. Other factors may need to be considered including the patient's reported functional limitations such as sitting or stair climbing and demographic information such as age, BMI, gender, and employment status.

Correlation of outcome scores

We found a significant, but low correlation between the MHHS and TDS among the symptomatic subgroups. Morlock et al (Morlock et al 2001) also reported a low correlation ($r = 0.32$) between activity level and the original Harris Hip Score (HHS). (Harris 1969) Their study differed from our study in the sample studied, Harris Hip Score version used and

methods of data collection. Their sample included older adults (mean 63 years) reporting higher functional levels (mean HHS 91) after a total hip arthroplasty (THA) compared to our relatively younger adults (mean age 36) reporting lower functional levels (mean MHHS 58) prior to surgical procedure. In addition, we collected data using the SAM device worn over a seven day period. Morlock et al used a custom device for one, twelve hour period. Despite differences in the methods, both studies found low correlations between the Harris Hip Score and total daily strides.

The MHHS contains a number of questions not related to walking ability, and likely the reason for the low correlation. Only one question is related to walking distance. Two questions relate to gait quality, 'how much do you limp' and 'need of an assistive device'. Four questions ask about other activities including sitting, stairs, putting on shoes and socks and the ability to take public transportation. The remaining question which accounts for 48% of the score is based on pain severity. The low correlation between the MHHS score and the TDS suggests that each tool is measuring a different construct and therefore both may be useful in measuring patient outcomes. The SAM provides an objective measure of walking ability and the MHHS provides information about pain and other functional limitations such as sitting and stair climbing.

We also found a low correlation between the UCLA and TDS. Sechriest et al (Sechriest et al 2007) found no relationship between the UCLA and monitored activity level ($r=0.02$) in young subjects after THA. Zahiri et al (Zahiri et al 1998) also assessed subjects after THA, however found a low (strength not reported) but statistically significant correlation. The lack of or low correlation may be related to the instructions of the questionnaire. The UCLA asks the subject to describe their activity level over the *last 6 months*. The SAM records the subject's *current activity level*. Therefore in its current form, the UCLA may not be an appropriate tool to measure current activity status but instead provide the previous activity level of the subject.

We found no correlation between the Marx and activity level. The intent of the Marx is to obtain the activity level of an athlete prior to injury, therefore instructs the patient to rate their activity level when performing at their healthiest and most active state. Therefore, it is not surprising that a correlation was not found between the Marx and total daily strides.

Finally, it is important to point out that all of the functional measures used in this study are subjective self-report measures that are completed by the subject on a single occasion. The SAM provides an objective method to monitor activity level over an extended period of time which could be useful in assessing treatment outcomes.

Limitations

The large variability in TDS combined with small sample sizes for some groups may limit our power to detect between-group differences. However, sample size and statistical power were maximized by the analytical method which allowed us to include data from each day with an adjustment for the clustering of data within a subject. The current study achieved adequate power of 0.80 or greater to detect between groups differences of at least 1,000 strides, a value we considered to be clinically important, but this level of difference was not observed. The maximum between-group difference observed in this study was 865 strides for the asymptomatic controls as compared to the OA subgroup.

The study was not powered to assess the potential role of covariates, such as age and BMI, in the association between activity level and hip disorder. We performed additional analysis to compare TDS across groups with age and BMI as covariates and the findings were unchanged. Group differences in TDS cannot be solely attributable to age and BMI.

Differences in age and BMI across the symptomatic subgroups are not unexpected and are reflective of the population as defined by our criteria. For instance, it is not surprising that the OA subgroup was older and had a higher BMI than other symptomatic subgroups.

We excluded 83 subjects for insufficient stride activity data (i.e., subject did not have 10 hours per day for 4 days including a weekend day). Compared to the subjects included in this study, the subjects excluded for insufficient stride data reported functional ability that was three points lower as measured by the MHHS function subscale. It is possible that the excluded subjects may have taken fewer strides than the subjects with valid stride data, thus artificially inflating our total daily strides. We believe systematic methods were necessary to reduce bias and limit inclusion of times the SAM was not worn. We used a previously published systematic method (King et al 2011) consistently across all groups and post hoc analysis showed no differences among asymptomatic and symptomatic subgroups in the number of days excluded from the analysis. For future studies, we recommend subjects complete a daily log of their activity that may be used to compare to the data collected by the SAM.

CONCLUSION

In summary, we found that subjects with a spectrum of hip disorders who have failed non-surgical management demonstrate fewer daily strides than asymptomatic controls. Surprisingly, we discovered that subjects with FAI or DDH demonstrated daily stride counts similar to asymptomatic controls. In addition, functional measures such as the Modified Harris Hip Score and the UCLA have low correlations to TDS among young and middle-aged adults with hip disorders. We have demonstrated that accelerometers can be used to monitor stride count in a clinical population and provide additional information about activity not represented by traditional functional measures. Future research is needed to determine if TDS changes after surgical intervention or if pre-surgical activity level predicts surgical outcomes.

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Findings: Young and middle-aged adults with hip disorders demonstrate fewer daily strides than asymptomatic controls, however some subgroups, FAI and DDH, demonstrated total daily strides similar to controls while reporting poor function. Functional measures such as the Modified Harris Hip Score and the UCLA have low correlations to total daily stride count among young and middle-aged adults with hip disorders.

Implication: Accelerometers can be used in a clinical population to provide additional information about activity not represented by traditional functional measures. Baseline data specific to young and middle-aged adults with hip disorders is provided.

Caution: There was large variability in total daily strides within each group and sample sizes were small.

Reference List

Amstutz HC, Thomas BJ, Jinnah R, Kim W, Grogan T, Yale C. Treatment of primary osteoarthritis of the hip. A comparison of total joint and surface replacement arthroplasty. *Journal of Bone and Joint Surgery*. 1984; 66:228–241. [PubMed: 6693450]

- 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. *Journal of Bone & Joint Surgery - British*. 2005; 87(7):1012–8.
- Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt L. Validation study of WOMAC: a health status instrument for measuring clinically important patient-relevant outcomes following total hip or knee arthroplasty in osteoarthritis. *Journal of Orthopaedic Rheumatology*. 1988; 1:95–108.
- Boenig DD. Evaluation of a clinical method of gait analysis. *Physical Therapy*. 1977; 57:795–798. [PubMed: 877147]
- Burnett RS, Rocca GJD, Prather H, Curry M, Maloney WJ, Clohisey JC. Clinical presentation of patients with tears of the acetabular labrum. *Journal of Bone and Joint Surgery*. 2006; 88:1448–1457. [PubMed: 16818969]
- Byrd JW, Jones KS. Prospective analysis of hip arthroscopy with 2-year follow-up. *Arthroscopy*. 2000; 16:578–587. [PubMed: 10976117]
- Cavanaugh JT, Coleman KL, Gaines JM, Laing L, Morey MC. Using step activity monitoring to characterize ambulatory activity in community-dwelling older adults. *Journal of the American Geriatrics Society*. 2007; 55:120–124. [PubMed: 17233695]
- Daniel J, Ziaee H, Pradhan C, Pynsent PB, McMinn DJW. Blood and urine metal ion levels in young and active patients after Birmingham hip resurfacing arthroplasty: four-year results of a prospective longitudinal study. *Journal of Bone and Joint Surgery - British*. 2007; 89-B:169–173.
- Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement - A cause for osteoarthritis of the hip. *Clinical Orthopaedics and Related Research*. 2003; 417:112–120. [PubMed: 14646708]
- Gosvig KK, Jacobsen S, Sonne-Holm S, Palm H, Troelsen A. Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. *Journal of Bone and Joint Surgery-American*. 2010; 92:1162–1169.
- Guevara CJ, Pietrobon R, Carothers JT, Olson SA, Vail TP. Comprehensive morphologic evaluation of the hip in patients with symptomatic labral tear. *Clinical Orthopaedics & Related Research*. 2006; 453:277–285. [PubMed: 17016215]
- Hack K, Di Primio G, Rakhra K, Beaulé PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. *Journal of Bone and Joint Surgery*. 2010; 92:2436–2444. [PubMed: 20962194]
- Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *Journal of Bone & Joint Surgery - American*. 1969; 51:737–755.
- Hirata S, Ono R, Yamada M, Takikawa S, Nishiyama T, Hasuda K, Kurosaka M. Ambulatory physical activity, disease severity, and employment status in adult women with osteoarthritis of the hip. *Journal of Rheumatology*. 2006; 33:939–945. [PubMed: 16652424]
- Karabulut M, Crouter SE, Bassett DR Jr. Comparison of two waist-mounted and two ankle-mounted electronic pedometers. *European Journal of Applied Physiology*. 2005; 95:335–343. erratum appears in *Eur J Appl Physiol*. 2006 Feb;96(3):334–5. [PubMed: 16132120]
- King WC, Belle SH, Eid GM, Dakin GF, Inabnet WB, Mitchell JE, Patterson EJ, Courcoulas AP, Flum DR, Chapman WH, Wolfe BM. Physical activity levels of patients undergoing bariatric surgery in the longitudinal assessment of bariatric surgery study. *Surgery for Obesity and Related Diseases*. 2011; 4:721–728. [PubMed: 19026376]
- Klaue K, Durnin CW, Ganz R. The acetabular rim syndrome. A clinical presentation of dysplasia of the hip. *Journal of Bone and Joint Surgery-British*. 1991; 73:423–429.
- Langlais F, Lambotte JC, Lannou R, Gedouin JE, Belot N, Thomazeau H, Friehe wtco J-M, Gouin F, Hulet C, Marin F. Hip pain from impingement and dysplasia in patients aged 20–50 years. Workup and role for reconstruction. *Joint Bone Spine*. 2006; 73:614–623. [PubMed: 17137820]
- Maheshwari AV, Malik A, Dorr LD. Impingement of the native hip joint. *Journal of Bone and Joint Surgery*. 2007; 89:2508–2518. [PubMed: 17974896]
- Maluf KS, Mueller MJ. Novel Award 2002. Comparison of physical activity and cumulative plantar tissue stress among subjects with and without diabetes mellitus and a history of recurrent plantar ulcers. *Clinical Biomechanics*. 2003; 18:567–575. [PubMed: 12880704]

- Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF. Development and evaluation of an activity rating scale for disorders of the knee. *American Journal of Sports Medicine*. 2001; 29:213–217. [PubMed: 11292048]
- Mavcic B, Iglic A, Kralj-Iglic V, Brand RA, Vengust R. Cumulative hip contact stress predicts osteoarthritis in DDH. *Clinical Orthopaedics & Related Research*. 2008; 466:884–891. [PubMed: 18288549]
- McCarney R, Warner J, Iliffe S, van Haselen R, Griffin M, Fisher P. The Hawthorne Effect: a randomised, controlled trial. *BMC Medical Research Methodology*. 2007; 7:30. [PubMed: 17608932]
- McClung CD, Zahiri CA, Higa JK, Amstutz HC, Schmalzried TP. Relationship between body mass index and activity in hip or knee arthroplasty patients. *Journal of Orthopaedic Research*. 2000; 18(1):35–9. [PubMed: 10716276]
- McDonald CM, Widman L, Abresch RT, Walsh SA, Walsh DD. Utility of a step activity monitor for the measurement of daily ambulatory activity in children. *Archives in Physical Medicine & Rehabilitation*. 2005; 86:793–801.
- Morlock M, Schneider E, Bluhm A, Vollmer M, Bergmann G, Muller V, Honl M. Duration and frequency of every day activities in total hip patients. *Journal of Biomechanics*. 2001; 34:873–881. [PubMed: 11410171]
- Mueller MJ, Maluf KS. Tissue adaptation to physical stress: a proposed “Physical Stress Theory” to guide physical therapist practice, education, and research. *Physical Therapy*. 2002; 82:383–403. [PubMed: 11922854]
- Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *Journal of Bone and Joint Surgery - British*. 2002; 84-B:556–560.
- Peelle MW, Della Rocca GJ, Maloney WJ, Curry MC, Clohisy JC. Acetabular and femoral radiographic abnormalities associated with labral tears. *Clinical Orthopaedics & Related Research*. 2005; 441:327–333. [PubMed: 16331022]
- Pollard TCB, Villar RN, Norton MR, Fern ED, Williams MR, Murray DW, Carr AJ. Genetic influences in the aetiology of femoroacetabular impingement: a sibling study. *Journal of Bone and Joint Surgery - British*. 2010; 92-B:209–216.
- Sechriest 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. *Journal of Arthroplasty*. 2007; 22:39–47. [PubMed: 17197307]
- Shepherd EF, Toloza E, McClung CD, Schmalzried TP. Step activity monitor: increased accuracy in quantifying ambulatory activity. *Journal of Orthopaedic Research*. 1999; 17(5):703–8. [PubMed: 10569479]
- Silva M, McClung CD, dela Rosa MA, Dorey FJ, Schmalzried TP. Activity sampling in the assessment of patients with total joint arthroplasty. *The Journal of Arthroplasty*. 2005; 20:487–491. [PubMed: 16124965]
- Silva M, Shepherd EF, Jackson WO, Dorey FJ, Schmalzried TP. Average patient walking activity approaches 2 million cycles per year. *The Journal of Arthroplasty*. 2002; 17:693–697. [PubMed: 12216021]
- Spencer JM, Loughlin J, Clipsham K, Carr AJ. Genetic background increases the risk of hip osteoarthritis. *Clinical Orthopaedics & Related Research*. 2005:134–137. [PubMed: 15685066]
- Tepper S, Hochberg MC. Factors associated with hip osteoarthritis: data from the first national health and nutrition examination survey (NHANES-1). *American Journal of Epidemiology*. 1993; 137:1081–1088. [PubMed: 8317437]
- Wynne-Davies R. Acetabular dysplasia and familial joint laxity: two etiological factors in congenital dislocation of the hip. A review of 589 patients and their families. *Journal of Bone and Joint Surgery - British*. 1970; 52:704–716.
- Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *The Journal of Arthroplasty*. 1998; 13:890–895. [PubMed: 9880181]

FIGURE 1a.

Samples of daily data that were *excluded* based on the criteria that the SAM must be worn a minimum of tens hours within the 24 hour period. Vertical axis is strides per minute. Horizontal axis is time of day in military time. All represent days where it appears that the SAM was not worn for a significant period of time. A) Subject demonstrated stride activity for approximately 6 hours. No strides were taken from noon to 10:00 pm or from midnight and 9:00 am. Total 1610 strides. B) Subject demonstrated stride activity for approximately 7 hours. No strides were taken from midnight to 4:00 pm. Total 1871 strides. C) Subject demonstrated stride activity for approximately 6 hours. No strides were taken from midnight to 8:00 am or from 3:00 pm to midnight. Total 4425 strides.

FIGURE 1b.

Samples of daily data that were *included* based on the criteria that the SAM must be worn a minimum of tens hours within the 24 hour period. Vertical axis is strides per minute. Horizontal axis is time of day in military time. All represent days where it appears that the SAM was worn throughout the day. A) Subject demonstrated stride activity over 14 hours, however demonstrated a 3 hour block of time with no stride activity recorded. Total time with recorded (14) minus block of time with no activity (3) equals 11 hours of stride recording. Total 2423 strides. B) Subject demonstrated stride activity for 18 hours of stride activity. Total 6116 stride. C) Subject demonstrated approximately 17 hours of stride activity. Total 10273 strides.

FIGURE 2.

Total strides per day by group. Values shown are the mean daily strides (horizontal lines) and standard deviations (boxes). The whiskers extending from the edges of the boxes represent the range of strides (minimum and maximum) taken per day. These summary data are presented using the raw data; however the data were log-transformed prior to statistical analysis.

Table 1

Clinical criteria needed to be included in the study. Subgroup classification was later confirmed intra-operatively.

	Symptoms location	Clinical exam	Imaging (Radiographic findings unless otherwise noted)	Common diagnosis
Femoroacetabular impingement (FAI)	-Hip pain (groin, buttock or lateral hip) -Hip symptoms for at least 3 months	-pain reproduced with anterior impingement test, indicating an intra-articular source -hip internal rotation with the hip at 90° 15°	Must have one or more of the following -Acetabular inclination (<0°) -Acetabular retroversion (crossover sign) -Anterior center edge angle (>30°) -Coxa profunda -Protrusion acetabuli -Femoral neck alpha angle 55°	Cam impingement Pincer impingement
Developmental Dysplasia of the Hip (DDH)		pain reproduced with anterior impingement test, indicating an intra-articular source	Must have one or more of the following -Tönnis angle > 10° ¹⁶ -Lateral center edge angle (LCEA) <25° ¹⁶ -Anterior center edge angle (ACEA) <20° ¹⁶	Acetabular dysplasia
Isolated Labral Tear (LT) No bony abnormalities		pain reproduced with anterior impingement test, indicating an intra-articular source	No structural abnormalities Positive finding of labral tear with magnetic resonance arthrography	Labral tear Chondral flap Internal derangement
Osteoarthritis (OA)		pain reproduced with anterior impingement test, indicating an intra-articular source	-50% loss of joint space	Endstage osteoarthritis

Table 2

Demographic information and self-report functional scores by subgroup.

	Asymptomatic Control Group	Symptomatic Subgroups				P-value, overall model comparing all groups
		Femoroacetabular impingement (FAD)	Developmental Dysplasia of the Hip (DDH)	Isolated Labral Tear (LT)	Osteoarthritis (OA)	
Gender						
Female N (%)	14 (70)	38 (51)	15 (62)	33 (92)	36 (53)	
Male N (%)	6 (30)	36 (49)	9 (38)	3 (8)	32 (47)	0.0006 ^a
Age (years)						
Mean SD	40.1 SD 6.9	31.9 SD 10.6	29.1 SD 7.5	35.3 SD 9.5	40.9 SD 8.2	<0.0001 ^b
BMI (kg/m ²)						
Mean SD	25.8 SD 5.7	25.4 SD 4.8	27.0 SD 5.1	25.1 SD 4.6	29.1 SD 6.0	0.0002 ^c
*MHHS						
Mean SD	N/A	59.9 SD 13.4	59.2 SD 11.2	58.7 SD 13.5	51.1 SD 11.9	0.0006 ^d
**MHHS Pain Subscale						
Mean SD	N/A	17.6 SD 7.4	16.3 SD 5.8	17.5 SD 6.9	16.8 SD 6.6	0.89
†MHHS Function Subscale						
Mean SD	N/A	36.9 SD 6.7	37.6 SD 5.7	35.9 SD 6.9	30.3 SD 7.0	<0.0001 ^e
UCLA						
Mean SD	N/A	6.4 SD 2.8	7.4 SD 2.4	5.7 SD 2.2	5.6 SD 2.4	0.02 ^f
Marx						
Mean SD	N/A	5.4 SD 6.0	7.5 SD 5.4	4.8 SD 5.1	1.8 SD 4.0	<0.0001 ^g

Table 3

Comparison of activity level collected by the Step Watch activity monitor (SAM).

		Symptomatic Subgroups				P-values	
Variables	Mean SD	Asymptomatic Control Group	Femoroacetabular impingement (FAI)	Developmental Dysplasia of the Hip (DDH)	Isolated Labral Tear (LT)	Osteoarthritis (OA)	
% Time spent at no activity <15 strides/min	*Total Daily Strides (TDS)	5192 SD 2164	5095 SD 2354	4627 SD 2291	4547 SD 2380	4327 SD 2075	contrast comparing asymptomatic to symptomatic groups‡
	% Time spent at low activity 15–40 strides/min	72.3 SD 8.8	73.2 SD 9.4	73.5 SD 9.3	74.6 SD 9.8	76.0 SD 9.0	0.04
	% Time spent at med activity 41–75 strides/min	18.3 SD 6.3	17.7 SD 6.5	18.3 SD 6.3	17.3 SD 6.1	16.1 SD 6.0	0.21
	% Time spent at high activity >75 strides/min	8.0 SD 3.9	7.7 SD 3.8	7.0 SD 4.0	6.9 SD 4.1	7.0 SD 3.6	0.42
		1.4 SD 1.4	1.4 SD 1.6	1.2 SD 1.2	1.2 SD 1.2	1.0 SD 1.1	0.15§
							0.18¶