Gait, Lower Extremity Strength, and Self-Assessed Mobility After Hip Arthroplasty

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Background. Rehabilitation services after hip arthroplasty (HA) usually occur in the first 6 months following surgery. Patients are discharged from rehabilitation when goals of functional independence in activities of daily living (ADL) and ambulation are achieved (1). Rehabilitation reevaluation beyond 6 months after surgery is not usually performed. Operative lower extremity (LE) muscle weakness and asymmetric gait patterns could lead to increased stresses on the nonoperative LE (2), an inability to perform higher level mobility functions, and an increased risk of falling (3).

Loizeau and colleagues (2) found that subjects fitted with a hip prosthesis walked more slowly and had longer stance duration and shorter stride length than able-bodied controls. The hip abductors on the operative side demonstrated reduced action, which was associated with poor trunk control during body weight transfer from the operative to the nonoperative LE.

The hip abductors assist in maintaining balance during single-leg stance (4,5). For a subject to be able to maintain balance and allow the foot of the swing leg to clear the ground, the stance-leg abductors must contract to prevent the pelvis from dropping on the opposite side. The gluteus medius and minimus are capable of pulling the pelvic rim toward the greater trochanter of the femur (4). This action is important for lateral stability and may be compromised following HA because the abductors are often surgically resected (6). Hip abductor and flexor strength on the operative side was shown to be weaker than the nonoperative side initially and 1 year after HA (2,7). If muscle weakness persists beyond initial rehabilitation, it may compromise lateral stability during walking. Indeed, we already know that hip abductor weakness is a key marker for community-dwelling fallers (8).

Maki (3) studied gait patterns, fear of falling, and falls in older adults. He found that a reduced speed of walking was associated with the fear of falling. The hip muscle weakness (2) noted after HA may contribute to a decrease in gait speed and a decrease in the ability to recover from a loss of balance. These decreases may create a fear of falling that limits functional ability and diminishes patient satisfaction with operative results.

Haworth and colleagues (9) followed 145 subjects for 9 months after HA surgery. Most subjects had their expectations for pain relief satisfied. However, a significant number expressed disappointment in their ability to perform domestic activities (e.g., housework and shopping) and social activities (e.g., visiting friends and going to church). Subjects from Haworth’s study were not evaluated objectively for gait problems or muscle weakness. According to Vaz and colleagues (10), following HA, hip abductor strength is related to the distance walked in the 6-minute walk test. For patients followed from presurgery to 6 months postoperatively, as hip abductor strength improved so did the distance achieved in the 6-minute walk test. This finding suggests that the problems subjects encountered when performing domestic activities and the dissatisfaction they had with their walking ability may have resulted from long-term LE muscle weakness.

The dissatisfaction with the ability to perform domestic and social activities may be based on the lack of mobility associated with weakness in the LE extremity. Therefore,
the purpose of this study was to determine if subjects 9 months to 6 years after HA surgery had fully recovered bila-
neral LE strength, a normalized gait pattern, and perceived normal functional mobility (11) when compared with an age- and gender-matched control group.

METHODS

Fifteen subjects who had undergone HA surgery and 15 age- and gender-matched controls participated. The overall mean age for the HA group was 59.9 years (SD 14.9; range 32–80), and the mean age for the control group was 60.2 years (SD 15.0; range 33–83). There were 10 women and 5 men in each group, and all were community dwellers and able to ambulate without assistive devices. All subjects had a Mini-Mental (12) score greater than 24. Subjects were so-
cially active and recruited from church groups, senior citi-
zens centers, and orthopedic practices. Inclusion criterion
for the HA group was that subjects were at least 9 months
doing not more than 72 months (6 years) status post HA. The
mean time duration since surgery for the HA group was
23.6 months (SD 14.8; range 9.0–61.2). Exclusion criteria
for both groups were past or current history of psychiatric
disorders or use of psychotrophic drugs; chronic medical ill-
ness (i.e., renal, metastatic cancer, or HIV); neurological
disorders such as stroke or transient ischemic attacks; se-
vere arthritis resulting in joint deformities of the knees, feet,
or hands or history of recurrent hip dislocations after HA
surgery; and uncontrolled hypertension or cardiac disease or
any disease that limited walking ability.

Subjects in both groups were recruited concurrently. In
the HA group, the reasons given for hip surgery were frac-
ture from a fall (n = 3), fracture from a motor vehicle acci-
dent (n = 2), and arthritis (n = 10). The 15 HA surgeries
were performed by 13 orthopedic surgeons at five different
hospitals in northeast Florida. There were no differences in
age, height, and weight (t test, p > .05) or gender between
the groups (Table 1).

All measurements were collected during a single session,
and all subjects were tested on one day. All testers were
physical therapists with at least 10 years of experience, met
standards of reliability for the test they provided, and were
blindfolded to group assignment. Subjects were asked to wear
comfortable clothing and walking shoes. The testing order
was randomized. The testing procedures were explained to
all subjects, and an approved human studies informed consent
document was signed before testing. The University of
Florida Health Sciences Center guidelines for conduct of re-
search involving human subjects were followed. Subjects
were tested to determine LE lateral dominance (13) and
completed the hip-rating questionnaire (11).

The hip abductors and extensors, quadriceps, and ankle
dorsiflexors of both lower extremities were tested and mea-
sured using a Spark handheld dynamometer (Spark Instru-
ments and Academics, Coralville, IA), which was shown to
be valid and reliable (14,15). Muscle testing was performed
by a single investigator blinded to group, demonstrating in-
tra-rater reliability over three trials (intraclass correlation
coefficient [1,1] = .89). Subjects were instructed to sit or lie
on their sides or stomachs and to contract the designated
muscle against the dynamometer resistance as applied by
the experimenter. Muscle testing positions were as de-
scribed in Smidt (16). Subjects performed a “make” test
(15), which is a maximum, static contraction held for 5 sec-
onds against resistance.

Footfall patterns were recorded, then analyzed, using a
gaitmat (GAITMAT II; EQ, Plymouth Meeting, PA). The
gaitmat consists of a flat, black, 4×1-m walking surface with
a series of embedded, pressure-sensitive switches con-
ected to a computer system. Subjects were asked to walk at
a self-selected, natural walking velocity for seven trials and
at a maximum walking velocity (“as fast as possible”) for
seven trials. The first two trials at each velocity were prac-
tice trials, and data were collected on the final five trials.
Subjects began to walk when cued by the investigator
(“Go”), stopped after each traverse of the gaitmat, and then
returned to the initial start position. The gaitmat had a ramp-
on and ramp-off area, so the initial three steps and the final
three steps were not included in the gait analysis. Our reli-
ability testing of the gaitmat for footprint/step length analy-
ysis resulted in an intraclass correlation coefficient of 0.99.

Data analysis was done using SAS software (SAS Insti-
tute, Cary, NC). Comparisons between and within groups
for the HA group nonoperative and operative LE and the
control group dominant and nondominant LE gait param-
ters of step and stride length, support base, step, swing,
stance, and single and double support time were made using
multivariate analyses of variance (MANOVA). The com-
mon MANOVA test, Pillai’s Trace, was performed for each
result. Each trial in the gait analysis equaled one traverse of
the gaitmat, which consisted of 2 to 5 cycles. Each cycle
consisted of 4 to 8 left and right steps for each subject; the
steps were summed to obtain the mean for each trial. The
number of cycles in each trial depended on the subjects’
step length. All gait parameters were individually recorded
for the left and right LE. When comparing between groups,
the nondominant LE of the control group was compared
with the operative LE of the HA group, and the dominant
LE of the control group was compared with the nonopera-
tive LE of the HA group. When comparing within groups,

<table>
<thead>
<tr>
<th>Table 1. Subject Characteristics (N = 30)</th>
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<tbody>
<tr>
<td>Characteristics</td>
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<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Age, y</td>
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<tr>
<td>SD</td>
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<td>Range</td>
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<td>Gender</td>
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<td>Height, m</td>
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<tr>
<td>SD</td>
</tr>
<tr>
<td>Weight, kg</td>
</tr>
<tr>
<td>SD</td>
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</tbody>
</table>

Note: HA = hip arthroplasty; NS = no significant difference between groups
at the .05 alpha level.
the nonoperative LE was compared with the operative LE in the HA group, and the dominant LE was compared with the nondominant LE in the control group.

Overall gait velocity was recorded separately as one measurement for each trial. The five gait velocity trials were added together to obtain the mean for each subject. Two-sample independent t tests were used to compare between-group differences for overall gait velocity. Differences in all gait parameters were deemed significant at \( p \leq .05 \).

MANOVA tests were performed to determine between- and within-group differences for HA and control groups for muscle strength testing. Between-group comparisons were made using the nondominant LE versus the operative LE and the dominant LE versus the nonoperative LE as with the gait parameters analysis. Differences were deemed to be significant at \( p \leq .05 \). Means of ratio data for the HA group operative/nonoperative LE muscle strength and the control group nondominant/dominant LE muscle strength for the quadriceps, ankle dorsiflexors, hip abductors, and hip extensors were used to determine 95% confidence intervals (CI). Intervals that did not include 1.0 were considered to be indicative of weakness.

Wilcoxon rank sum tests were used to compare between-group differences for the domains of impact, pain, gait, and function on the hip-rating questionnaire. Differences were deemed significant at \( p \leq .05 \).

### Results

The overall gait velocity at self-selected speeds was not significantly different between groups. There was a significant difference \((p = .04)\) at maximum walking speed between the HA \((1.5 \text{ m/s}; \text{SD} .40)\) and control group \((1.8 \text{ m/s}; \text{SD} .34)\) (Table 2). Gait parameters of step and stride length, support base, step, swing, stance, and single and double support time were not significant between groups. One HA subject and one control subject were excluded from the gait data collection analysis due to technical difficulty with the computer equipment.

We compared the HA and control group muscle strength scores of the quadriceps, ankle dorsiflexors, hip abductors, and hip extensors of the right and left LE for effect (Table 3). The interactions of side \((p = .0007)\), side \(\times\) group \((p = .03)\), and muscle \((p = .0001)\) were significant. The HA group’s nonoperative LE strength \((14.9 \text{ kg; SD} 5.5)\) was less than the operative LE \((16.6 \text{ kg; SD} 5.0)\), and both nonoperative and operative lower extremities were less than the nondominant \((17.6 \text{ kg; SD} 4.7)\) and dominant \((18.1 \text{ kg; SD} 5.3)\) LE of the control group. This difference is demonstrated in Figure 1.

We compared the within-subject effect of muscle strength in the muscle groups for the HA group and control group using a ratio of operative/nonoperative muscle group muscle strength scores and nondominant/dominant muscle group muscle strength scores for each of the four muscle groups tested. Three of the four muscle groups (quadriceps, hip abductors, and hip extensors) in the HA group did not include 1.0 in their CI, indicating muscle weakness (Table 4). Muscles indicating weakness in the HA group were the hip abductors \((0.84; \text{SD} .3)\), hip extensors \((0.87; \text{SD} .04)\), and quadriceps \((0.87; \text{SD} .05)\).

We compared the HA and control group scores for each of the four domains of impact, pain, gait, and function on the hip-rating questionnaire. The HA group had significantly lower scores \((p = .01)\) in the domains of impact \((p = .002)\), pain \((p = .004)\), and function \((p = .004)\). Notably, under the domain of function, 67% of the HA group indicated that they were unable or required a handrail to ascend and descend a flight of stairs. There was not a significant difference between the HA and control group in the domain of gait \((p = .07)\).

### Discussion

Increases in gait pace are an integral part of daily living and are necessary for hurrying to answer a ringing telephone, crossing at intersections, and taking public transpor-

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**Table 2. Results of Gait Velocity Analysis Between the Hip Arthroplasty and Control Group During Maximum and Self-Selected Walking Speeds**

<table>
<thead>
<tr>
<th>Velocity Group</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>SE</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>14</td>
<td>1.8 m/s</td>
<td>0.34</td>
<td>0.09</td>
<td>.04*</td>
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<tr>
<td>HA</td>
<td>14</td>
<td>1.5 m/s</td>
<td>0.40</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Self-selected</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>14</td>
<td>1.3 m/s</td>
<td>0.21</td>
<td>0.06</td>
<td>.12</td>
</tr>
<tr>
<td>HA</td>
<td>14</td>
<td>1.1 m/s</td>
<td>0.29</td>
<td>0.08</td>
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</tr>
</tbody>
</table>

*Note: SD = standard deviation; SE = standard error; HA = hip arthroplasty.

*Significant result.

**Table 3. MANOVA Test Results for Interactions Between and Within the Hip Arthroplasty (HA) and Control Groups During Muscle Strength Testing of the Hip Abductors, Hip Extensors, Quadriceps, and Ankle Dorsiflexors for the Dominant and Nondominant Lower Extremity (LE) of the Control Group and the Operative and Nonoperative LE of the HA Group**

<table>
<thead>
<tr>
<th>Effect</th>
<th>F Value</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
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</tr>
<tr>
<td>Side</td>
<td>14.6</td>
<td>.0007*</td>
</tr>
<tr>
<td>Side (\times) group</td>
<td>5.6</td>
<td>.03*</td>
</tr>
<tr>
<td>Muscle</td>
<td>97.7</td>
<td>.0001*</td>
</tr>
<tr>
<td>Muscle (\times) group</td>
<td>0.31</td>
<td>.82</td>
</tr>
<tr>
<td>Side (\times) muscle</td>
<td>2.0</td>
<td>.14</td>
</tr>
<tr>
<td>Side (\times) muscle (\times) group</td>
<td>2.2</td>
<td>.12</td>
</tr>
</tbody>
</table>

*Significant result.
tation. These activities are not usually included in the initial rehabilitative goals following HA surgery but are activities you would expect our HA group with a mean of 23.4 months (range 9.0–61.2; SD 14.76) post-surgery to be able to master. Although the HA group did not demonstrate an asymmetric gait pattern, they were not able to achieve the gait speed (1.2 m/s) needed to cross an intersection safely (17).

In addition, the majority of the HA group indicated that they had difficulty ascending and descending stairs. Our findings demonstrate that activities as functional as safely crossing a busy intersection or stairclimbing may be limited in subjects with HA far beyond the initial recovery period.

Whereas our control group showed no difference in overall muscle strength between their dominant and nondominant LE, the HA group showed a significant difference in the overall muscle strength between the nonoperative and operative LE. The data show that the operative LE hip abductors were the weakest muscle group in the HA group.

Weaker hip musculature on the operative side in subjects with HA surgery may contribute to poor trunk control during body-weight transfer from the operative to the nonoperative side (2). Poor trunk control may be more pronounced when walking at faster speeds and may have contributed to the decreased gait velocity of HA subjects compared with controls.

The HA group may have had a more difficult time correcting imbalances during gait because of weaker hip abductor strength on the surgical side. Weak hip abductors as seen after HA surgery may suffice for walking at a self-selected pace consistent with our findings but may not be adequate for assisting with trunk stability at faster walking speeds. The instability created by weak proximal hip musculature can further contribute to the fear of falling and thus to a decrease in gait pace, as shown by Maki (3).

On the hip arthritis impact questionnaire, the HA group scored lower than the control group in overall impact, pain, and functional ability, indicating that they felt more impact on their lives, more pain during activities, and less mobility than the control group. The decrease in mobility is important considering the relatively young age of the HA group (59.9 years; SD 14.9; range 32–80).

Conclusions
The findings of this study indicate that, whereas subjects with hip arthroplasty surgery may be able to perform some ADL, many may continue to have significant operative lower extremity muscle weakness. They also note a detrimental impact on their lives and continuing pain and decreased mobility levels far beyond the time of initial rehabilitation. The hip arthroplasty group was not able to walk as fast as the control group and had operative LE muscle weakness in the more proximal hip muscles. Ambulation requiring obstacle negotiation includes stepping over objects, ascending and descending stairs, walking faster when crossing a street, stepping on and off an escalator or elevator, and making quick turns, quick starts, and quick stops. All of these activities require adequate muscle strength and gait speed to be performed safely and should be reevaluated in hip arthroplasty subjects over a period of several years.

People who have undergone hip arthroplasty are usually seen at yearly intervals by their orthopedic surgeon. This study shows that therapeutic intervention with an emphasis on hip muscle strengthening is needed at stages beyond the initial rehabilitation. We suggest that a rehabilitation evaluation should occur at yearly intervals and should emphasize muscle strength testing and functional testing of higher-level skills. Rehabilitation should include training in higher-level functional activities, advanced balance activities, and activities essential for lower extremity muscle strengthening with emphasis on the operative extremity hip abductors, hip extensors, and quadriceps (18). Decreasing the residual disability and increasing activity may be beneficial for the physical, functional, and psychosocial levels of individuals following hip arthroplasty surgery.

Acknowledgments
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References

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