

# Assessment of Hip Abductor Muscle Strength. A Validity and Reliability Study

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**Background:** Hip abductors are the most important muscles around the hip joint. It is therefore essential to assess their function in a valid and reliable way. Since the optimal body posture for the assessment of hip abductor strength is unknown, we tested the validity and reliability of unilateral hip abductor strength assessment in three different body positions. We hypothesized that the validity would be better in the side-lying position because of the consistent stabilization of the contralateral (untested) hip.

**Methods:** Sixteen healthy subjects participated in two identical testing sessions. Unilateral isometric hip abductor muscle strength was measured, with use of a stabilized commercial dynamometer, with the subject in the side-lying, supine, and standing positions. Construct validity was based on concomitant recordings of gluteus medius electromyographic activity from the tested and contralateral hips. The body position permitting greater muscle activation and abductor strength on the tested hip, while minimizing muscle activation in the contralateral hip (that is, lower contralateral-to-tested electromyographic ratio), was considered the most valid. Coefficients of variation, the Bland and Altman limits of agreement, and intraclass correlation coefficients were calculated to determine test-retest reliability of hip abductor strength.

**Results:** Maximal hip abductor strength was significantly higher in the side-lying position compared with the standing and supine positions ( $p < 0.05$ ). The contralateral-to-tested electromyographic ratio for the side-lying position was significantly lower than that for the supine and the standing position ( $p < 0.01$ ). Test-retest reliability of strength measurements in terms of coefficients of variation (3.7% for side-lying, 6.1% for supine, and 4.2% for standing) and limits of agreement ( $\pm 6.9\%$  for side-lying,  $\pm 8.4\%$  for supine, and  $\pm 7.5\%$  for standing) was better in the side-lying position. All intraclass correlation coefficients were high to moderate (0.90 for side-lying, 0.83 for supine, and 0.88 for standing).

**Conclusions:** The side-lying body position offers the most valid and reliable assessment of unilateral hip abductor strength.

**Clinical Relevance:** We recommend the use of the side-lying body position whenever hip abductor function is assessed.

Hip abductors are generally considered the most important muscles surrounding the hip joint because of their function as pelvic stabilizers, especially during single-limb stance. Patients with an insufficiency of the hip abductor muscles may have development of a Trendelenburg gait<sup>1</sup> or, in severe cases, a Duchenne gait<sup>2</sup>. For the hip specialist, it is therefore crucial to be able to interpret these compensatory mechanisms<sup>3</sup> and to objectively evaluate hip abduction function. Hip abductor muscle deficits, both in terms of weakness<sup>4,5</sup>

and functional limitations<sup>6</sup>, have been documented in patients before and after total joint arthroplasty. As a consequence, hip surgeons have focused on preserving<sup>7</sup> or restoring these muscles<sup>8</sup>, whereas clinicians have emphasized the role of rehabilitation<sup>9,10</sup>. Furthermore, hip abductor muscle weakness has been associated with overuse injuries<sup>11</sup>, adductor strains<sup>12</sup>, and patellofemoral pain<sup>13</sup>.

Hip abductor strength can be assessed with use of different measurement tools and body positions. Besides the

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unreliable manual muscle testing<sup>14</sup>, isokinetic devices<sup>15-18</sup> and portable dynamometers (handheld or stabilized)<sup>13,19,20</sup> have been used to assess hip muscle function in both the research and clinical settings, and their test-retest reliability has been shown to be acceptable<sup>19,20</sup>. However, the most essential difference between hip abductor strength results seems to reside in subject positioning: lateral, or side-lying, compared with supine compared with upright, or standing. The side-lying position is the most commonly adopted position to test muscle strength in clinical settings<sup>21</sup>, and it is also recommended by most manufacturers of isokinetic testing devices. Advocates of the supine position underline the advantage of its gravity neutrality and the possibility for patients to avoid lying on the affected side<sup>19</sup>, while the standing position has been suggested to be the most functional position for the assessment of hip abductor strength<sup>18</sup>. However, to our knowledge, the validity and reliability of these measurements in the side-lying, supine, and standing positions have never been examined so the optimal posture for hip abductor strength assessment remains to be determined.

The main purpose of this study was to assess the construct validity of unilateral hip abductor strength assessment in three body positions commonly used in the clinical setting (side-lying, supine, and standing). Construct validity was based on isometric strength and concomitant electromyographic recordings of the gluteus medius muscles from the tested and contralateral hips during unilateral maximal hip abduction. It was hypothesized that the side-lying posture would offer the most valid assessment of unilateral hip abductor strength because of consistent stabilization of the contralateral, untested hip. A secondary aim was to establish the test-retest reliability of hip abduction strength data obtained in the side-lying, supine, and standing body positions.

## Materials and Methods

### Subjects and Experimental Procedures

Sixteen healthy subjects (eight men and eight women) recruited from the clinical staff volunteered to participate in this study. The age, height, and body mass of the subjects were an average (and standard deviation) of  $31 \pm 6$  years,  $176 \pm 10$  cm, and  $70 \pm 11$  kg, respectively. Exclusion criteria consisted of any disease, disorder, or behavior that could have caused side-to-side differences in hip abductor muscle mass and function. Prior to participation in the study, all subjects provided informed consent. The study was conducted according to the Declaration of Helsinki, and the study protocol was approved by the local ethical committee.

To investigate the validity of hip abductor muscle strength assessment, unilateral maximal isometric strength and bilateral electromyographic activity of the gluteus medius muscle (that is, the main hip abductor muscle<sup>22</sup>) were quantified in three different body positions (supine, standing, and side-lying). Construct validity was assessed with the use of two assumptions: (1) compared with other body positions, the most valid position would permit greater electromyographic activity of the tested gluteus medius compared with the con-

tralateral homonymous muscle (that is, the stabilizer) and (2) compared with other body positions, the most valid position would show higher hip abduction strength. With this idea in mind, the contralateral-to-tested electromyographic ratio (see the section on Gluteus Medius Electromyographic Activity) of the gluteus medius muscle and unilateral abduction strength were compared across positions. We tested healthy rather than impaired hips because the validity of our main outcome (contralateral-to-tested electromyographic ratio) was based on the absence of side-to-side differences in hip abduction muscle mass and strength, which would have invalidated any side-to-side electromyographic comparison.

To investigate the test-retest reliability of hip abductor muscle strength assessment, two identical test sessions separated by forty-eight to seventy-two hours were completed at the same time of the day. Subjects were asked not to take part in vigorous physical activity for two days before each test date.

### Hip Abductor Muscle Strength

Isometric maximal voluntary contraction strength of the hip abductor muscles was measured with a portable dynamometer (Lafayette Manual Muscle Test System model 01163; Lafayette Instrument Company, Lafayette, Indiana) fixed to a custom-made frame. Stabilized portable dynamometers have recently been shown to provide reliable data for the assessment of hip abductor muscle strength<sup>19</sup>. The dynamometer consists of a load-cell force-detecting system able to measure forces of up to 136 kg with an accuracy of 0.45 kg and a resolution of 0.2 kg. The custom-made frame was firmly fixed to a physical therapy treatment table with use of screw clamps. The frame (Fig. 1) consisted of two vertical steel bars (50 cm in height), attached perpendicular to the extremities, on a horizontal steel sheet (70 cm wide and 20 cm deep). A third horizontal steel bar (59 cm wide) was individually adjusted perpendicular to the two vertical bars.

Assessments started following a standardized warm-up (a duration of five minutes at an intensity of 100 W) on a cycle ergometer. After having received standardized instructions, subjects performed a series of familiarization trials consisting of three or four submaximal hip abductions per side in each of the three experimental positions, randomly presented. Then, maximal voluntary contraction strength was measured for the dominant and nondominant sides in the three body positions, with side and position being randomized within each test session.

For the lateral position, the subjects lay on their side on the treatment table and the dynamometer was fixed to the horizontal steel bar (Fig. 1, A). The contralateral hip and knee joints were positioned at 30° of flexion for stability and comfort. The subjects were not allowed to use the upper extremities for trunk stabilization during the measurements. In this position only, the weight of the tested limb was consistently assessed to allow correction of maximal voluntary contraction strength values. For the supine position, the subjects lay on their back on the treatment table and the dynamometer was fixed to one of the vertical steel bars (Fig. 1, B). A

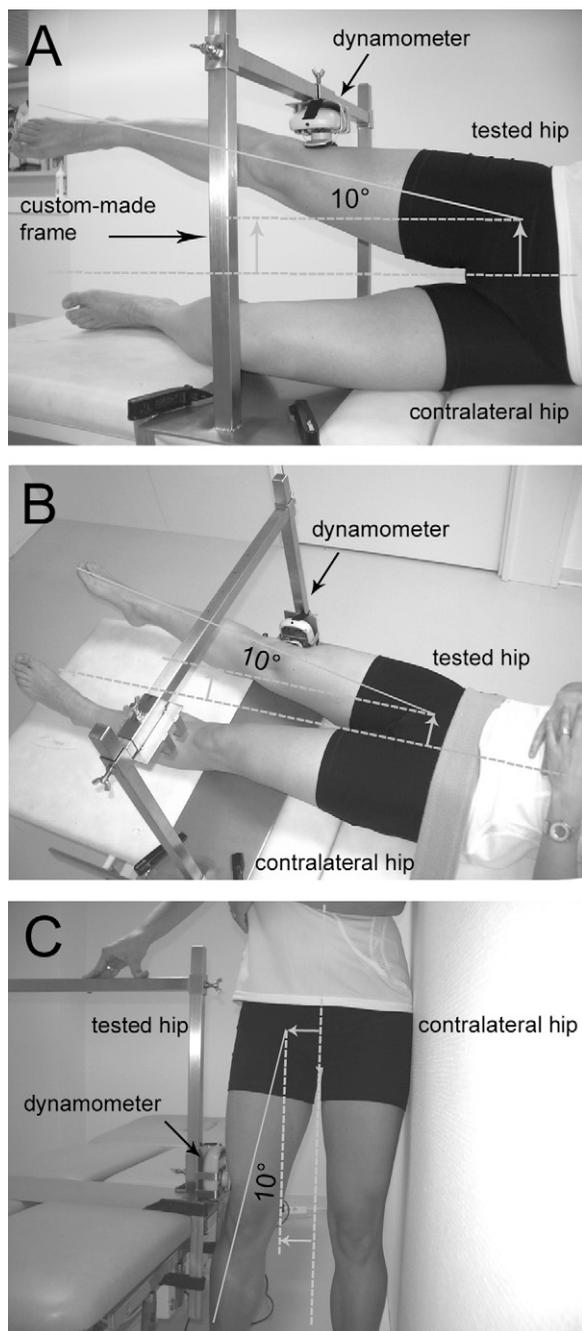


Fig. 1  
Subject positioning and dynamometer fixation on the custom-made frame for the assessment of maximal isometric hip abductor strength, showing the axis of the body and the axis of the tested limb. A: The side-lying position. B: The supine position. C: The standing position.

wide abdominal belt was placed across the anterior superior iliac spines and the treatment table to stabilize the pelvis. Use of the upper extremities for further stabilization of the trunk was not permitted. For the upright position, the subjects stood next to the treatment table, with the contralateral side of the body abutted against the wall for body stabilization (Fig. 1, C).

The dynamometer was fixed outside one of the vertical steel bars. The subjects were allowed to put two fingers on the upper part of the frame for further body stabilization.

Whatever the experimental position, the knee of the tested limb was fully extended during the maximal voluntary contraction and the tested hip was at  $10^\circ$  of abduction<sup>13</sup>. The center of the dynamometer pad was located 5 cm proximal to the lateral femoral condyle. Two examiners inspected the whole-body position and electromyographic recordings of the subject during the maximal voluntary contraction trials to ensure minimal pelvic rotation and minimal flexion and rotation about the hip. For each experimental condition (side and position), two to three maximal voluntary contraction trials were permitted. The subjects were instructed to produce their maximal force without any concern for the rate of force development. The duration of these contractions was approximately four seconds, and sixty seconds of rest were interspersed between trials. A third trial was completed only if the difference between the first two maximal voluntary contractions was  $>10\%$ . The highest maximal voluntary contraction strength value for each side and position was retained. Maximal voluntary contraction strength data provided by the dynamometer (in kilograms) were consistently normalized to body weight.

#### *Gluteus Medius Electromyographic Activity*

Electromyographic activity was recorded by a single-differential bipolar surface electrode (DE-2.1; Delsys, Boston, Massachusetts). The distance between the recording bars of the bipolar electrode was 1 cm. Self-adhesive tape was used to fix recording electrodes to the skin. Electromyographic signals were amplified 1000 times and bandpass filtered (20 to 450 Hz) before being sampled at 1 kHz. Surface electromyographic sensors were positioned on the right and left gluteus medius muscles according to SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) recommendations ([www.seniam.org](http://www.seniam.org)). A self-adhesive square ( $5 \times 5$ -cm) ground electrode was placed on the right wrist. Before the application of electromyographic sensors, the skin was shaved and cleaned with an alcohol preparation pad. The skin was marked with indelible ink to ensure identical placement of the electromyographic sensors in test and retest sessions.

During all of the maximal voluntary contraction trials, the electromyographic activity of the gluteus medius of the tested hip and of the contralateral hip was recorded. The root-mean-square electromyographic amplitude was calculated with use of a window length of 125 milliseconds and a window overlap of 62.5 milliseconds. For each maximal voluntary contraction, the highest electromyographic amplitude obtained over one second was calculated. Only the highest electromyographic amplitude of the two maximal voluntary contraction trials performed in the same conditions was retained. The contralateral-to-tested electromyographic ratio was calculated by dividing the electromyographic amplitude of the gluteus medius in its stabilizing function (contralateral hip) by the electromyographic amplitude of the gluteus medius of the tested hip, and it was expressed as a percentage.

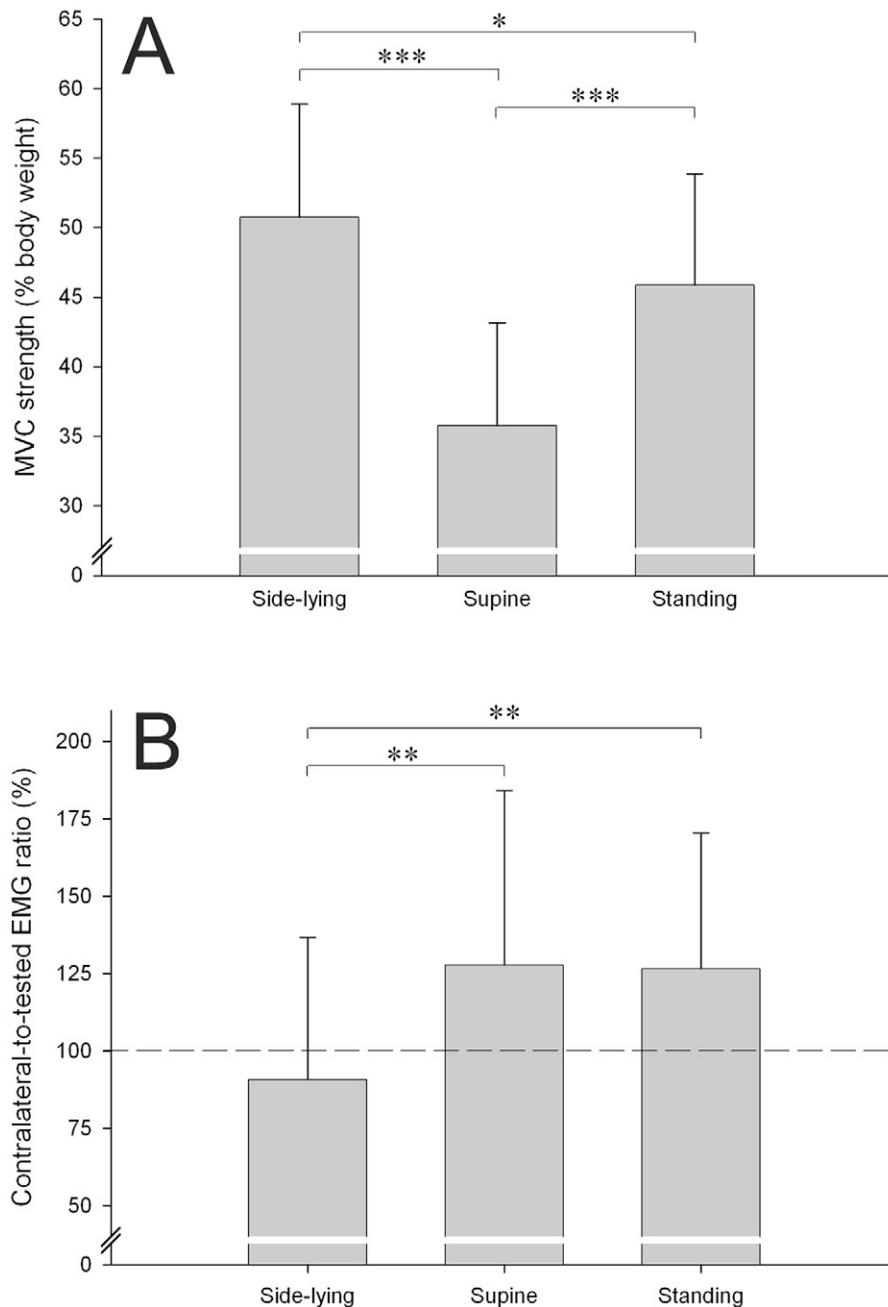


Fig. 2  
Hip abductor strength and gluteus medius electromyographic results. The values are given as the mean and the standard deviation. *A*: Maximal voluntary contraction (MVC) strength (normalized to body weight) in the side-lying, supine, and standing positions. The differences between positions were significant: \* $p < 0.05$  and \*\*\* $p < 0.001$ . *B*: Contralateral-to-tested electromyographic (EMG) ratio during maximal isometric hip abduction in the side-lying, supine, and standing positions. The differences between positions were significant: \*\* $p < 0.01$ .

### Statistical Analysis

We hypothesized that the validity of hip abductor strength assessment is better in the side-lying position; therefore, we tested whether the maximal voluntary contraction strength and the contralateral-to-tested electromyographic ratio were

significantly influenced by body posture, that is, whether strength and electromyographic ratio were, respectively, the highest and the lowest in the side-lying position. Consequently, a three-way repeated-measures analysis of variance with position (side-lying, supine, and standing), session (test

and retest), and side (dominant and nondominant) as within-subject independent variables was conducted on maximal voluntary contraction strength and contralateral-to-tested electromyographic ratio. In the case of significant main effects, Tukey post hoc tests were used with a Bonferroni adjusted  $p$  value. The level of significance was set at  $p < 0.025$ . Normality of distribution was assessed with use of the Shapiro-Wilk  $W$  test. Statistical analyses on electromyographic data were performed with use of the natural logarithm of the data, because of non-normality. For better clarity, electromyographic data are presented in raw values.

We assessed test-retest reliability of hip abductor maximal voluntary contraction strength with the intraclass correlation coefficients (2,1)<sup>23</sup> and 95% confidence intervals. As a general rule, we considered an intraclass correlation coefficient of  $>0.90$  as high, between 0.80 and 0.90 as moderate, and  $<0.80$  as insufficient<sup>24</sup>. Coefficients of variation and the 95% limits of agreement described by Bland and Altman<sup>25</sup> were used to further explore the reliability of maximal voluntary contraction strength in the three body positions. For each subject, coefficients of variation were calculated according to the formula: (standard deviation of test and retest measurements/mean of test and retest measurements)  $\times$  100. Limits of agreement were obtained in the following manner: (1) for each subject, the difference between test and retest measurements was plotted against the average value of the two trials; (2) the presence of homoscedasticity was verified; and (3) 95% limits of agreement were calculated as  $1.96 \times$  the standard deviation of the differences between the two trials<sup>25</sup>. Systematic biases were identified with use of paired  $t$  tests.

#### Source of Funding

There was no external source of funding.

## Results

### Muscle Strength

No significant interactions were found ( $p > 0.38$ ) for maximal voluntary contraction strength, while a main effect of position was detected ( $p < 0.001$ ). The highest and lowest maximal voluntary contraction values were observed in the side-lying and supine positions, respectively (Fig. 2, A). The maximal voluntary contraction strength in the side-lying position was 30% higher than that in the supine position ( $p < 0.001$ ) and 10% higher than that in the standing position ( $p < 0.05$ ). The maximal voluntary contraction strength in the standing position was also significantly higher than that in the supine position ( $p < 0.001$ ). No main effect of session ( $p = 0.31$ ) or side ( $p = 0.08$ ) was found.

### Electromyographic Activity

No significant interaction was found for the contralateral-to-tested electromyographic ratio ( $p > 0.11$ ), while a main effect of body position was observed ( $p < 0.001$ ). The electromyographic ratio in the side-lying position was significantly lower than both the supine and standing ratios ( $p < 0.01$ ), which were almost identical (Fig. 2, B). Interestingly, the contralateral-

to-tested electromyographic ratio of the gluteus medius was  $<100\%$  only in the side-lying position. No main effect of session ( $p = 0.08$ ) and side ( $p = 0.11$ ) was observed for the electromyographic ratio. When expressed as a raw (non-normalized) value, the highest electromyographic activity occurred in the standing position (mean and standard deviation,  $104 \pm 53$  mV for the tested hip and  $126 \pm 67$  mV for the contralateral hip) while the lowest electromyographic activity was recorded in the supine posture (mean,  $63 \pm 40$  mV for the tested hip and  $72 \pm 40$  mV for the contralateral hip).

### Test-Retest Reliability

Test-retest reliability of maximal voluntary contraction strength measurements was better in the side-lying position in terms of the coefficient of variation (3.67% for side-lying, 6.11% for supine, and 4.22% for standing) and limits of agreement ( $\pm 6.87\%$  for side-lying,  $\pm 8.37\%$  for supine, and  $\pm 7.48\%$  for standing). Systematic biases were not significant for the three body positions ( $-1.20\%$  for side-lying,  $-0.34\%$  for supine, and  $-0.62\%$  for standing). All intraclass correlation coefficients were high to moderate (0.902 for side-lying, 0.826 for supine, and 0.880 for standing), with overlapping 95% confidence intervals (0.743 to 0.965 for side-lying, 0.571 to 0.936 for supine, and 0.691 to 0.956 for standing).

## Discussion

The results of this study indicated that the isometric abduction strength of the hip was the highest and the contralateral-to-tested electromyographic ratio was the lowest in the side-lying position compared with the standing and supine body positions; that is, the validity was greater in the side-lying body position. Moreover, this study provided evidence to indicate that test-retest reliability of measurements of maximal voluntary contraction strength of the hip abductor muscles obtained with use of stabilized portable dynamometers was better in the side-lying posture than in the standing or supine position.

### Considerations on Construct Validity

Theoretically, and according to the bilateral deficit principle<sup>26</sup>, during unilateral maximal voluntary efforts, the designated agonist muscle should show greater activation than the contralateral homonymous muscle. The bilateral deficit is indeed defined as a reduction in the amount of force exerted by a single limb during a maximal bilateral contraction compared with the force associated with a maximal unilateral contraction<sup>26</sup> because of reduced muscle activation during bilateral actions<sup>27</sup>. Specifically, in this study, the electromyographic activity of the gluteus medius during its designated test was compared with the simultaneous activity of the contralateral homonymous muscle with use of the contralateral-to-tested electromyographic ratio. For maximal voluntary contraction in the supine and standing positions, electromyographic ratios of  $>100\%$  indicated higher activation of the contralateral than of the tested gluteus medius, and therefore the actual occurrence of bilateral rather than unilateral actions. This inevitably re-

duced the extent of the abduction force generated by the tested hip. On the other hand, the relatively low contralateral-to-tested electromyographic ratio observed in the side-lying position (approximately 90%) confirmed the validity of this experimental position for minimizing the occurrence of a bilateral deficit and, therefore, maximizing unilateral hip abduction strength output.

#### *Considerations on Supine, Standing, and Side-Lying Assessments*

The supine position can be adopted to assess hip abduction strength with the main advantage being to avoid gravity correction of force data<sup>19</sup>. Our construct validity and test-retest reliability results, however, do not support the use of this posture. Compared with the two other positions, the supine position demonstrated the lowest maximal voluntary contraction strength and the highest electromyographic ratio, as well as lower reliability (although moderate). The extremely low electromyographic activity of the tested gluteus medius observed in this position indicates that efferent neural drive to this muscle was clearly submaximal, reflecting suboptimal motor unit recruitment and/or discharge rate. This is likely attributable to poor body stabilization with use of the abdominal belt (Fig. 1, B) compared with lateral body support provided by the wall or by the table in the standing and side-lying positions, respectively. Future investigations, therefore, have to weigh the advantage of gravity neutrality against the poor validity of hip abductor strength assessment in the supine position.

Standing has been defined as the most physiological<sup>28</sup> and functional<sup>18</sup> position for hip abduction function assessment, as the majority of daily living activities involve hip abductions performed in weight-bearing conditions. Nevertheless, the use of the erect posture was not supported by the construct validity results in this study, while test-retest reliability was similar, although slightly inferior, to the side-lying position. During hip abduction in the upright position, subjects stand on the contralateral limb, thereby activating the contralateral hip abductors to prevent the pelvis from tilting down on the test side. This results in extremely high levels of activation of both gluteus medius muscles. Standing is the only one of the three positions considered in the present study in which pelvis stabilization has to be performed against gravity, and this might account for the extremely high electromyographic activity (the highest overall) of the contralateral, stabilizing gluteus medius muscle.

Obviously, gravity plays an important role in hip abductor strength assessment. In the side-lying position, the tested gluteus medius muscle worked against gravity, while the treatment table provided considerable body and pelvis stabilization of the contralateral side. Such consistent body stabilization, compared with the supine and standing conditions, resulted in the highest hip abduction strength and most optimal muscle activation strategy (that is, the lowest electromyographic ratio), as well as in the best test-retest reliability.

#### *Recommendations for Clinicians and Practitioners*

Our results indicate that, contrary to the measurement of the majority of lower-extremity muscle groups (for example, knee extensors, and ankle plantar flexors), unilateral measurement of hip abductor muscle strength is extremely challenging and proper body posture is crucial for executing such tasks. Considering that bilateral strength asymmetries (that is, the involved compared with the uninvolved side) are commonly assessed in patients<sup>15,16,29</sup> and healthy<sup>17</sup> individuals, it is essential that unilateral hip abductor strength is measured with use of a valid and reliable, yet simple, methodology that can be used in routine clinical practice. The findings of the present study clearly show that construct validity and high test-retest reliability were achieved exclusively in the side-lying posture; therefore, we strongly recommend this body position for the measurement of unilateral hip abductor strength whatever the setting (clinical or research), the tool, and the methodology adopted (isokinetic testing or manual muscle testing).

The supine position does not appear to be the optimal position for hip abduction muscle strength assessment, and it should therefore be avoided in favor of the valid and reliable side-lying position. In the case of patients who are unable to lie on the affected side because of pain in the hip<sup>18</sup>, the standing position should be preferred to the supine position but preferably not for bilateral comparisons.

#### *Limitations of the Study*

Our study had a few limitations. First, although two investigators (K.S.W. and J.F.G.) were in charge of visual control of body positioning, we could not totally exclude any pelvic movement in the sagittal plane and any rotation or flexion about the hip joint. We only measured electromyographic activity of the gluteus medius muscle despite being aware that it is the main, but not the only, hip abductor muscle. Moreover, the use of surface electromyography as a construct measure in our study has some limitations<sup>30</sup>. Finally, in order to compare electromyographic activity between the two sides, the experiments were conducted with use of subjects with symmetrical hip abductor muscle mass and strength. Our findings, at least those related to the validity of the side-lying position, should also be extended to people who have hip impairments. In fact, the use of the electromyographic ratio as a construct measure for validity has no rationale in the presence of hip function asymmetries, such as those observed in orthopaedic patients<sup>5</sup>. However, we acknowledge that further research would be necessary to test the reliability of hip abductor strength assessments in patients with actual hip disability or problems and to investigate whether the surgeon's qualitative assessment of hip abductor strength is associated with the quantitative findings in the present report. ■

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