

# Arm Use After Left or Right Hemiparesis Is Influenced by Hand Preference

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**Background and Purpose**—Despite strong evidence for hand preference and its impact on motor performance, its influence on stroke rehabilitation has not been routinely considered. Previous research demonstrates that patients with hemiparetic stroke use their ipsilesional, nonparetic arm 5 to 6 times more frequently than their paretic arm, but it is unknown if such use varies with laterality of hemiparesis. The purpose of our study was to determine if the right arm is used more frequently in right-handed patients with stroke.

**Methods**—We assessed relative use of the right, left, and both arms with wrist accelerometers on patients with unilateral, paretic stroke matched for degree of paresis (12 with right hemisphere damage, 17 with left hemisphere damage) and 25 neurologically intact control participants as they performed the Arm Motor Ability Test.

**Results**—We showed: (1) ipsilesional arm use was greater after right hemisphere damage than left hemisphere damage; (2) the left hemisphere damage group used both arms together more often than the right hemisphere damage group but less often than the control group; and (3) both stroke groups used their contralesional, paretic arm to the same degree.

**Conclusions**—These findings emphasize the influence of hand preference on arm use after stroke for the ipsilesional but not the contralesional arm. Although both stroke groups used their ipsilesional more than their contralesional arm, the difference was greater for the right hemisphere damage group who used their ipsilesional arm 4 times more frequently than their contralesional arm, whereas the left hemisphere damage group used their ipsilesional arm 2 times more frequently than their contralesional arm. (*Stroke*. 2009;40:545-550.)

**Key Words:** functional laterality ■ paresis ■ psychomotor performance ■ rehabilitation ■ stroke

Despite strong evidence for hand preference and its impact on motor performance,<sup>1-4</sup> its influence on stroke rehabilitation has not been routinely considered. One recent study suggested that hand preference influenced treatment outcome as evidenced by greater improvement when the treated, hemiparetic arm was the right, preferred arm rather than the left arm. Of course, the influence of other deficits that are differentially associated with left or right hemisphere damage (LHD and RHD, respectively) could not be ruled out definitively.<sup>5</sup> Nonetheless, these results suggest that the impact of hand preference on stroke outcome deserves further study.

There is substantial evidence that in right-handers, the 2 limbs perform differently,<sup>2-4,6-8</sup> right hand performance is faster than left hand performance,<sup>1</sup> and the right, preferred hand is used more frequently than the left, nonpreferred hand.<sup>9,10</sup> The most obvious example of this asymmetry is handwriting, in which the right hand is used almost exclusively with far greater facility.

In addition, there are significant differences in performance between the right and left arm after unilateral stroke, especially when the “unaffected” limb ipsilesional to the stroke is

examined.<sup>11-17</sup> These differences have been associated with differences in laterality of brain damage because hand preference effects were controlled by comparing performance of a particular hand in the stroke groups with that of a neurologically intact group using the same hand.

However, one recent study directly compared the paretic limbs of patients with left or right hemisphere stroke and found that basic motor functioning (eg, tone, grip strength) was better in the paretic limb when it was the preferred limb, which was attributed to the preferred limb’s better neuromuscular condition.<sup>18</sup> In contrast, based on self-report of paretic arm use, the patients in this study did not report any differences in the use of their paretic limb whether it was the preferred or nonpreferred limb. This latter finding is somewhat surprising, although the lack of differences may be related to 2 issues. First, use of the paretic limb may not depend on hand preference if the degree of paralysis is severe enough to preclude any significant functional movement. Second, they used a self-report measure of use (Motor Activity Log<sup>19</sup>), which may not be as sensitive as quantitative measures of use.<sup>20</sup>

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The impact of hand preference on relative use of the nonparetic limb after stroke is obviously extremely important in patients with severe hemiplegia who must use their nonparetic limb to compensate for hemiplegia. This conclusion is supported by a study that showed patients with unilateral stroke used their ipsilesional, nonparetic arm 3 to 6 times more than their paretic arm.<sup>20</sup> However, this study did not assess whether ipsilesional limb use was influenced by laterality of lesion or whether the preferred or nonpreferred limb was paretic. Therefore, the purpose of the current study was to determine if right hand preference influences the relative use of each limb after stroke. We measured arm use quantitatively in a right-handed healthy control group (HC) and right-handed patients with stroke with right or left hemiplegia due to LHD or RHD, respectively, as they performed activities of daily living. We predicted: (1) the right nonparetic limb in patients with RHD would be used more frequently than the left nonparetic limb in patients with LHD; (2) contralesional arm use would be greater for the right, preferred arm of the LHD group than for the left, nonpreferred arm of the RHD group even when the groups were matched for degree of hemiplegia; and (3) the LHD group would use both arms together more than the RHD group.

## Materials and Methods

### Participants

Twenty-nine right-handed patients with stroke (17 with LHD and 12 with RHD) and 25 right-handed HC subjects were examined after obtaining approval from the Veterans' Administration Institutional Review Board and informed consent from each participant according to the Declaration of Helsinki. All subjects were screened and excluded based on a history of (1) substance abuse and/or severe psychiatric diagnosis; (2) nonstroke neurological diseases for the patients with stroke and all neurological diagnoses for the control subjects; and (3) peripheral movement restrictions such as neuropathy or orthopedic disorders.

Patients were considered hemiparetic if they had a contralesional grip strength 1.5 SDs below normative standards<sup>21</sup> and at least 1.5 SDs less than ipsilesional grip strength using a hand dynamometer. The Fugl-Meyer Upper Extremity Motor Score was used as an additional measure of hemiparesis,<sup>22</sup> and the Edinburgh Inventory was used to document hand dominance before stroke.<sup>10</sup> To match stroke groups on hemiparesis, 4 LHD patients in the top 80th percentile on the Fugl-Meyer Upper Extremity Motor Score were excluded from analyses, but they met all other study inclusion criteria, including the presence of imaging data. The 25 HC subjects were age-, education- and sex-matched to the patients with hemiparetic stroke.

### Lesion Measurement

MRIs (Phillips Edge 1.5 Tesla scanner) were obtained in 26 patients with stroke with slice thickness of 5 mm and a slice gap of 1 mm. CTs (Picker PQ6000) were obtained in 3 patients with stroke with slice thickness of 8 mm above the posterior fossa and no slice gap. A board-certified neurologist, who was blinded to the behavioral characteristics of the patients, outlined the area of damage for each patient on 11 standardized horizontal sections derived from the DeArmond atlas<sup>23</sup> using T1-weighted MRI images for anatomic detail and T2-weighted images and fluid-attenuated inversion recovery images to specify borders of the damaged tissue. These tracings were retraced into a computer program that used an algorithm to calculate lesion volume and location within each hemisphere from both MRIs and CTs.<sup>24</sup> This information was used to assess lesion volumes and intrahemispheric lesion locations in the 2 stroke groups.

## Experimental Setup

Limb activity in each limb was assessed during the Arm Motor Ability Test (AMAT) with small, commercially available accelerometers worn on both wrists. These devices have been shown to accurately measure duration of movement during laboratory and home tasks.<sup>25</sup>

### Arm Motor Ability Test

The AMAT is an assessment of activities of daily living that has demonstrated validity and reliability.<sup>26</sup> It was administered in the standard manner except that one item was omitted (prop on extended arm) because difficulty level varied with participant body dimension. The modified AMAT consists of 12 items, which include such tasks as drinking, combing hair, and opening a jar. Each task is modeled by the examiner at the time verbal instructions are given. A laminated template is placed on the test table for standardized object placement and for standardized participant arm placement between tasks. The participants were asked to perform each task as they normally did in everyday life without any cues regarding what arm should be used or any speed requirements. The scoring of the AMAT is based on quality of movement in the contralesional arm and is therefore a reflection of the influence of paresis rather than overall performance regardless of what arm or arms are used to complete the task. Therefore, the AMAT did not provide a score of overall functional ability that would allow us to assess the relationship between different patterns of arm use and ability to perform activities of daily living.

### Activity Monitors

The activity monitors were Actigraph GT1 monitors manufactured by Actigraph, LLC. They are 3.8×3.7×1.8 cm in dimension, weigh 27 g,<sup>25</sup> and they contain one megabyte of nonvolatile flash memory, and a rechargeable 3.7-V battery supplies power. Data are transferred between the GT1 and a Microsoft-compatible PC through a standard USB 2.0 interface. The GT1 mol/L measures varying accelerations in movement. These acceleration signals are sampled and digitized, yielding an output signal that corresponds linearly to changing accelerations. Output signals are represented by a series of numbers, called raw counts, indicating the level or intensity of movement for each epoch. Data are gathered continuously and recorded at 2-second intervals for this study.

As a result of the sensitivity of the activity monitors, even very small arm movements result in a large fluctuation in raw counts. Because we were interested in the duration of movement and not its amplitude, we transformed the data using a threshold filter technique that has been shown to be a valid and reliable measure of movement duration.<sup>25</sup> Each epoch with a raw count  $\geq 1$  was assigned a value of 1 for the right arm and 4 for the left arm, and each epoch with a raw count of  $<1$  was assigned a value of 0 for the right arm and 2 for the left arm. Transformed values for the right and left arms were then summed to determine which arm was being used during each epoch; a value of 2 indicated neither arm was being used, 3 indicated just the right arm was being used, 4 indicated just the left arm was being used, and 5 indicated both arms were being used.

The activity monitors were worn on both of the participant's wrists directly over the dorsal surface. The participant was instructed to place both forearms onto designated lines on the AMAT template on the table and asked to return to this position and remain as motionless as possible between tasks. The start time for the AMAT was noted from a timing device that was synchronized with the PC before the test was administered. At the conclusion of the last subtest, a stop time for the AMAT was noted so that during data transformation, no extraneous data would be included in the analysis (eg, when removing the activity monitors from the participant's wrists).

### Limb Apraxia

Ideomotor limb apraxia was assessed using a published test with good interrater reliability<sup>27,28</sup> that assesses imitation of 15 gestures (5 meaningless, 5 intransitive movements [eg, gesture for "okay"], 5 transitive movements [eg, brush teeth]). When errors in internal hand position, hand orientation, target (eg, brush nose, not teeth) and/or

**Table 1. Descriptive Data**

Variable*	HC	RHD	LHD
Number	25	12	17
Age, years	64.0 (8.3)	59.2 (9.9)	65.1 (11.9)
Education, years	15.2 (2.1)	14.1 (2.2)	15.1 (2.9)
Sex, % male	84.0%	58.3%	82.4%
Handedness, Edinburgh	89.8 (14.8)	93.8 (8.2)	90.0 (13.0)
Lesion volume, cm <sup>3</sup>		136.3 (105.5)	72.8 (54.1)
Fugl-Meyer score†		32.8 (28.7)	46.9 (19.9)
Limb apraxia, % apraxic		8.3%	64.7%
Grip strength, right‡	47.4 (5.8)	46.8 (10.4)	31.5 (19.3)
Grip strength, left‡	48.8 (6.3)	24.8 (25.3)	51.1 (9.2)

\*Mean with SD in parentheses except where indicated.

†Motor upper extremity, maximum score 66.

‡T score with mean=50, SD=10.<sup>21</sup>

body part as object (eg, extend index finger to brush teeth) were made, the item was scored as incorrect. Patients were considered apraxic if they made such errors on 4 or more of the 15 movements (2 SDs greater than the normal control group).<sup>27</sup>

## Statistical Analyses

Group differences in patient characteristics and in total time completing the task and in time spent moving and not moving were analyzed with univariate analyses of variance (ANOVAs) and significant group differences were followed by post hoc Tukey tests to identify which of the 3 groups performed differently. The percentage of time each arm was used was analyzed with 3 separate univariate ANOVAs to assess group (control, RHD, LHD) differences for the 3 types of arm use (right arm only, left arm only, and both arms), and these ANOVAs were also followed by post hoc Tukey tests. The contralesional and ipsilesional arm use data were directly analyzed for the stroke groups by performing ANOVAs with group (LHD, RHD) and arm use (contralesional, ipsilesional) as factors.

## Results

Table 1 summarizes the characteristics of each group. There were no significant group differences in age ( $P=0.26$ ), education ( $P=0.37$ ), sex ( $P=0.18$ ), or degree of hand preference (Edinburgh,  $P=0.66$ ). There were significant group differences in both right grip strength ( $F[2,53]=9.13$ ,  $P<0.001$ ) and left grip strength ( $F[2,53]=16.04$ ,  $P<0.001$ ). Follow-up analyses showed these differences were always due to greater impairment in the contralesional limb; the LHD group had lower right grip strength than both the RHD group ( $P<0.01$ ) and HCs ( $P<0.01$ ), whereas the RHD group had lower left grip strength than both the LHD group ( $P<0.001$ ) and the HCs ( $P<0.001$ ). No patients had visual neglect as measured by line cancellation, although 2 patients showed unusual errors. One LHD patient with attentional deficits made bilateral errors with 5 on the contralateral side and 7 on the ipsilateral side, and another LHD patient made 2 errors in the ipsilesional hemisphere. Neither of these patterns is consistent with traditional definitions of visual neglect.<sup>29</sup>

Patients with LHD or RHD did not significantly differ in years poststroke ( $P=0.27$ ), hemiparesis (Fugl-Meyer,  $P=0.13$ ), or lesion location (number of patients with lesions anterior,

**Table 2. AMAT Duration**

AMAT Duration, minutes*	HC	RHD	LHD
Total time	21.4 (2.7)	26.2 (5.7)	24.2 (3.5)
Movement	7.1 (2.0)	12.2 (4.7)	10.5 (2.4)
No movement	14.2 (2.7)	14.0 (3.4)	13.7 (2.4)

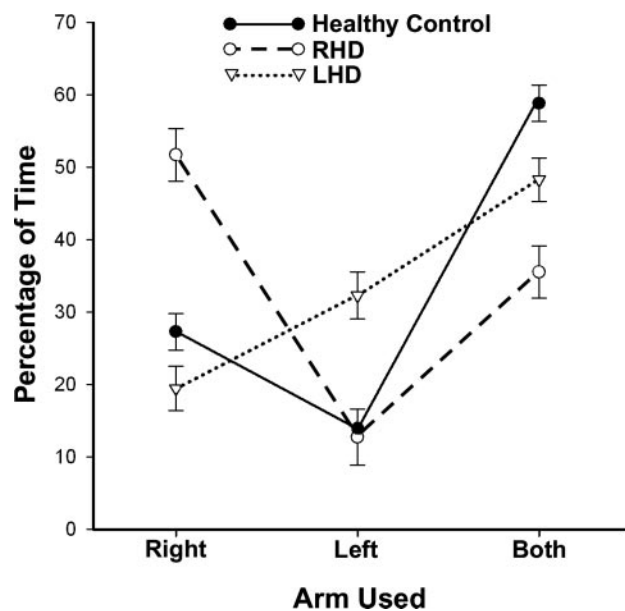
\*Mean with SD in parentheses.

posterior, or anterior and posterior to the central sulcus [ $\chi^2=0.221$ ,  $P=0.90$ ]). However, the RHD group demonstrated larger lesion volume ( $F[1,28]=4.52$ ,  $P<0.05$ ) and the LHD group demonstrated a higher incidence of limb apraxia ( $\chi^2=9.22$ ,  $P<0.01$ ). Strokes were localized in the middle cerebral artery distribution in 90% of the patients with stroke (88% LHD, 92% RHD) and in the anterior cerebral artery distribution or a combination of 2 of the 3 arterial distributions in the remaining 3 patients with stroke.

As seen in Table 2, and confirmed by ANOVA, there were significant group differences in total time completing the task ( $F[2,53]=7.07$ ,  $P<0.01$ ) and in time spent moving ( $F[2,53]=14.42$ ,  $P<0.001$ ), but no significant group differences in time spent without movement ( $P=0.84$ ). Tukey post hoc analyses revealed that the HC group spent less time moving than either the LHD ( $P<0.01$ ) or RHD ( $P<0.001$ ) groups. Because the time without movement mainly reflects instruction time, the difference in total time across groups was driven primarily by the stroke groups' increased time to complete the AMAT tasks. Subsequent analyses focus only on the time spent moving. To allow for further comparisons of group differences in time spent moving each limb, minutes spent moving each arm were converted to percentages of the total time moving the right, left, or both arms.

To compare the stroke groups' arm use with the control group, the percentage of time each arm was used was analyzed using 3 separate ANOVAs. As can be seen in Figure 1, there were significant group differences for each arm use category (right arm used,  $F[2,53]=24.37$ ,  $P<0.001$ ; left arm used,  $F[2,53]=11.53$ ,  $P<0.001$ ; both arms used,  $F[2,53]=14.56$ ,  $P<0.001$ ). However, the pattern of group differences varied. For right arm use only and left arm use only, both stroke groups used their ipsilesional arm more than the control group regardless of whether or not the arm was preferred. In each case, the stroke groups used their ipsilesional arm more than the other stroke group used their contralesional arm; the RHD group used just their right arm more often than either the HC subjects ( $P<0.001$ ) or the LHD group ( $P<0.001$ ) whose right arm use did not differ from each other. Similarly, the LHD group used just their left arm significantly more than either the HC group ( $P<0.001$ ) or the RHD group ( $P<0.01$ ) whose left arm use did not differ from each other. Finally, the HC group used both arms significantly more than the 2 stroke groups ( $P<0.05$ ), and the LHD group used both arms significantly more than RHD patients ( $P<0.05$ ).

Direct comparison of ipsilesional and contralesional use in the patients with stroke is displayed in Figure 2, which shows that the pattern of group differences varies as a function of arm used. Although the RHD group demonstrated greater use of their ipsilesional arm relative to the LHD group, contralesional

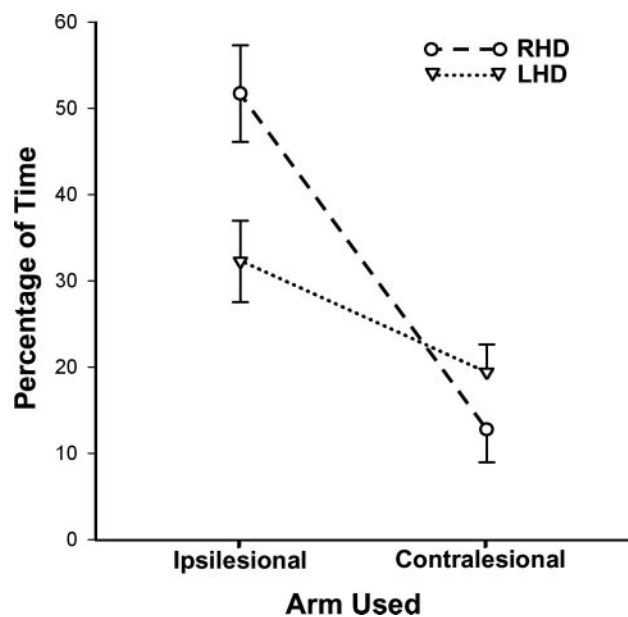


**Figure 1.** Percentage of time spent moving each arm alone and both arms together for the HC group and the stroke groups with LHD and RHD. Mean  $\pm$  SE.

sional use was comparable for the 2 stroke groups. This pattern of results was confirmed statistically by using a group (RHD, LHD) by arm used (ipsilesional, contralesional) repeated-measures ANOVA, which demonstrated significant main effects for group ( $F[1,27]=6.05$ ,  $P<0.05$ ) and arm used ( $F[1,27]=20.78$ ,  $P<0.001$ ) and a significant group  $\times$  arm-used interaction ( $F[1,27]=5.29$ ,  $P<0.05$ ) related to the RHD group's predicted greater ipsilesional arm use ( $F[1,28]=7.06$ ,  $P<0.05$ ). In contrast, contralesional arm use did not vary between the 2 groups ( $P=0.19$ ), which was inconsistent with our prediction that the LHD group would demonstrate greater contralesional, right, preferred arm use.

### Discussion

Our results demonstrate that use of the ipsilesional, but not the contralesional, limb after unilateral stroke is influenced by hand preference in right-handed patients. RHD patients used their ipsilesional, right, preferred limb more than LHD patients used their ipsilesional, left, nonpreferred limb and more than healthy right-handers. In addition, LHD patients used both arms together more than RHD patients, even when the degree of hemiparesis was equivalent between the 2 groups. However, the control group used both hands together more frequently than either of the stroke groups, consistent with previous use data,<sup>20</sup> suggesting that although the method of measurement was different, the results were similar. More specifically, in the current study, RHD patients used their ipsilesional limb alone approximately 4 times more frequently than their contralesional limb, whereas LHD patients used their ipsilesional limb alone approximately 2 times more frequently than their contralesional limb. The previous report<sup>20</sup> concluded that ipsilesional use was 3 to 6 times greater than contralesional use in a hemiparetic stroke group of 10 patients that included an unspecified number of patients with right or left paresis. Our findings



**Figure 2.** Percentage of time moving the ipsilesional and contralesional arm for the patients with stroke with LHD and RHD. Mean  $\pm$  SE.

show that these previous figures overestimate ipsilesional use for those with LHD. Most importantly, our results demonstrate that there are significant differences in ipsilesional and bilateral arm use, but not contralesional arm use, after RHD or LHD.

We believe that these differences in hand use across the 3 groups are related to hand preference effects. Although the RHD group had larger lesions than the LHD group ( $P=0.045$ ,  $\eta^2=0.143$ ), it is unlikely that lesion volume differences explain the group differences in arm use. If the differences were caused only by increased lesion volume, the RHD group would have more likely exhibited more severe hemiparesis, which was not the case, based on grip strength and Fugl-Meyer assessments of motor functioning. In addition, ipsilesional grip strength was comparable for the 2 stroke groups despite greater lesion volume in the RHD group.

These results also cannot be explained by a higher degree of right hand preference in the RHD patients because degree of hand preference (prestroke for the stroke group), as measured by the Edinburgh Handedness Questionnaire, was comparable across the groups. We also considered several explanations related to hemisphere-specific cognitive deficits, including intentional motor neglect, visual neglect, and spatial deficits, which are more common after RHD,<sup>29</sup> and limb apraxia, which is more common after LHD.<sup>27</sup> None of the deficits associated with RHD were a good explanation because most primarily affect the contralesional limb or hemisphere, and there were no differences in use for the contralesional limb of the RHD and LHD groups.

Limb apraxia, which was more common after LHD than RHD, could potentially decrease the LHD group's use of the ipsilesional limb in the real world as a result of decreased efficiency due to spatial and temporal deficits.<sup>30</sup> However, this decrease in efficiency is just as likely to increase the time



using the ipsilesional limb to compensate for decreased efficiency. Furthermore, limb apraxia affects both limbs after LHD, so it should also impact on use of the contralesional limb and both limbs together. Our results show that contralesional limb use was similar in the 2 stroke groups, and the LHD group used both limbs together more than the RHD group. Therefore, although limb apraxia cannot be definitively ruled out as an explanation of our LHD findings, we believe that the most likely explanation for our pattern of findings is a hand preference effect, which results in greater ipsilesional use for the RHD group and greater bilateral use for the LHD group.

These differences in use should have strong implications for rehabilitation. One of the most prevalent forms of rehabilitation, constraint-induced movement therapy,<sup>31–33</sup> restrains the unaffected arm of the patient to encourage use of the affected arm regardless of the patient's hand preference. Recovery is often measured by the degree of use in the affected arm both in laboratory settings and in everyday situations.<sup>34</sup> Although increased use of the contralesional, affected limb either by itself or with the ipsilesional limb may be positive for independent functioning, it is clear from our data that in patients who have not received constraint-induced movement therapy and who in many cases would not be eligible for such training because of severe hemiparesis, the ipsilesional limb is used more frequently than the contralesional limb, especially when the ipsilesional limb is the right, preferred arm. These findings suggest that constraint-induced movement therapy's goal of increasing contralesional arm use is likely to be more difficult after RHD than LHD because of the influence of hand preference, although we are not aware of any studies that have compared the impact of constraint-induced movement therapy after RHD and LHD.

One limitation of the present study was the relatively brief duration (25 minutes) of the AMAT tasks. Although assessment of more sustained activity may provide a more representative sample of real-world movement, our results in the control group were comparable to the use measures obtained in a previous study<sup>20</sup> that sampled activity at home over many hours suggesting our data are representative. In addition, because we could not assess quality of performance on the AMAT, we could not examine the relationship between arm use after stroke and functional performance. However, most studies that have examined functional deficits after unilateral stroke have found a comparable level of impairment after RHD and LHD<sup>35</sup> suggesting the possibility that the differences we have reported in hand use may not be associated with differential functioning.

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### Disclosures

None.

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