Original Article

Late Recovery from Stuttering: The Role of Hand Dominancy, Fine Motor and Inhibition Control

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Objective: There are controversial reports about factors that affect recovery from stuttering. In the present study, the effect of hand dominancy, fine motor and inhibition control on late recovery from stuttering was investigated among a group of Kurdish-Persian children who stuttered in Iran.
Method: Twenty-two Kurdish-Persian children aged 7-14 years who stuttered were followed for 6 years. Based on the evaluation of three experienced speech therapists and parental judgments, these children were classified into recovered or persistent groups. Data about fine motor control of hand and inhibition control were obtained, using Purdue Pegboard and Victoria Strop Color Word Tests, respectively. Risk factors including sex, age, and family history of stuttering, handedness, inhibitory control and fine motor control of hand were compared between the groups and modeled to predict recovery from stuttering using logistic regression.
Results: From the 22 participants, 5 (22.7%) recovered from stuttering. The recovered and persistent groups did not show significant differences in the interference effect. By dividing the scores of the Purdue Pegboard tests to the right and left hand, we created a new Handedness Index (HI). HI was significantly higher in the recovered group. The score of right hand was higher than the left in the recovered group, but no difference was found between the two hands in the persistent group. Among the investigated risk factors, only HI could predict the recovery from or persistency of stuttering with 94% sensitivity and 84% specificity.
Conclusion: Handedness Index can predict the recovery from stuttering significantly among children who stutter.

Key words: *Hand Fine Motor Control, Inhibition Control, Recovery from Stuttering*

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Stuttering is a dynamic speech motor disorder that involuntarily interrupts the temporal aspects and coordination between the subsystems of speech structures (1, 2). The disorder affects 1% of the adult population with an estimated incidence of 5-8% (3, 4). Many studies have investigated the different aspects of stuttering, but the causes of this disorder are still unknown. Nevertheless, a decrease with age was established in the prevalence of stuttering. Previous studies have reported high levels of spontaneous recovery from stuttering 3 to 5 years after onset (3). However, the biological and environmental factors determining the persistency of or recovery from stuttering are not yet well-understood (3). Although it has been reported that most natural recovery takes place before the age of seven, recovery can happen at any age (5). According to the time elapsed from the onset of stuttering, two types of recovery, early and late, have been identified (6). Very few studies have investigated late recovery from stuttering (7).

Several factors such as sex, age of onset, family history of the disorder and severity of stuttering have been reported as predictors for persistency of or recovery from stuttering (3, 8). Some studies reported the relation between inhibitory control and dysfluency in normal children and those with attention deficit hyperactivity disorder (9). It has been reported that self-regulation and inhibition problems as well as high nonfluency may have similar pathogenic mechanisms (10). Based on these suggestions, a few recent studies reported lower inhibitory control in people who stutter compared to those who do not (11). However, the effect of inhibitory control on recovery from stuttering has not been studied yet.

Another important factor is handedness and hand motor control. Studies have shown that left handedness is more prevalent in people who stutter, and it has been suggested that right handedness increases the chance of

recovery (12). Therefore, an etiological relation between complication of cerebral dominance and stuttering such as disruption, abnormality, or abnormal pattern of brain laterality has been proposed. Also, neuroimaging studies have indicated hyper-activation of the right hemisphere and bilateral cerebellar activity in people who stutter (13-15). Moreover, motor disruptions in speech and non-speech orofacial and finger movements have been reported (16).

Bilingualism, as a multidimensional and complicated phenomenon, can also affect the onset and development of stuttering (17, 18). Earlier studies have reported a high prevalence of stuttering among bilinguals compared with monolinguals (19, 20), although this has not been confirmed in subsequent studies (21). Regardless of the controversies about the role of bilingualism on the development of stuttering, few studies have investigated recovery from stuttering in bilinguals. Howell, Davis, and Williams (2009) reported an increased risk of stuttering and a lower chance of recovery from stuttering among bilinguals compared to monolinguals (22). They suggested further studies on recovery from stuttering among bilinguals.

Considering the above mentioned, we aimed to investigate the late recovery from stuttering in a group of Kurdish-Persian bilingual children who stutter. Moreover, in addition to previously investigated factors such as age, sex, and family history of the disorder, we investigated the role of inhibition control, fine motor skills, and handedness on recovery from stuttering.

Materials and Method

Participants:

Thirty-seven Kurdish-Persian bilingual children (26 boys and 11 girls) aged 7-14 years who suffered from stuttering were enrolled in the study during 2007. The study was conducted in Javanroud, located in Kermanshah province, West Iran. The first language of the city is Kurdish and children usually learn Persian as their second language at school. All of our participants were born to Kurdish native parents. They were Kurdish native speakers and had learned Persian from television, media, and formal education at school. Teachers had referred them as people with stuttering in 2007. Then they were invited to participate in the study. After obtaining the written informed consent from all parents, spontaneous speech samples in both languages were videotaped. Kurdish and Persian speech samples were obtained by Kurdish and Persian interviewers, respectively, under friendly interviewing conditions. Speech samples were obtained using methods such as story telling using serial pictures and free discussions about interesting topics for students.

To diagnose people who stutter, three registered speech language pathologists who had at least five years of experience working with Kurdish-Persian bilinguals who stutter analyzed four spontaneous speech samples (two samples in each language). One of the speech language pathologists was a Kurd and the other two were Persian native speakers. Finally, participants who were identified as stutterers by teachers, diagnosed as stutterers in both languages by the three speech language pathologists based on the evaluation of the four speech samples in Kurdish and Persian, and confirmed as stutters by parents continued their participation in the study. According to this multistep procedure, 37 students were identified as stutterers, but two were excluded from the study. One of the boys was not identified as a stutterer by his parents and the other had only paused before speaking Persian words but did not show any signs of dysfluency in Kurdish.

Procedure:

The parents of the 35 participants completed questionnaires consisting of information about demographic characteristics and stuttering history. The family history of stuttering was also obtained from the parents using a checklist that investigated first and second degree relatives with stuttering. Parents were asked to write any relatives that had stuttering or recovered from it in the checklist.

Six years later in 2013, the 35 children who stuttered were contacted and invited to participate in the second phase of the study. Since the researchers could not contact and find the 13 families, ultimately, the data of 22 participants including 14 boys and 8 girls were collected. The participants were examined again in the four speech samples in both languages by previous clinicians and methods. Participants who were identified as non-stutterers in both languages by the three speech therapists and were confirmed to be fluent speakers by their parents were categorized as the recovered group. Therefore, the participants were divided into two recovered and persistent groups. Through a careful interview, data were obtained on medication and speech therapy from both groups. Then, handedness was assessed by the Persian version of The Edinburgh Handedness Inventory. This inventory includes questions about which hand is used by the subject for several everyday activities. Each question is scored on a five-point Likert scale from always right (+10) to always left (−10). After the summation of scores, +40 and -40 were considered as cutting points for truly right and truly left laterality, respectively. The scores between these two points were considered as ambidextrous (23).

Later, having used the Lafayette Instrument Purdue Pegboard Test Model 32020, we evaluated the finger/hand function, dexterity, and laterality in the participants. The test has been used widely to evaluate hand laterality and motor control in a broad range of brain damages and dysfunctions (24-26). The subjects completed three separate test batteries including right hand (30 seconds), left hand (30 seconds), and assembly (60 seconds) tests according to the instructions. By dividing the right to left hand scores,

we created a handedness index. Finally, the inhibition control among the participants was investigated using the computer version of the Victoria Stroop Color Word Test (27). The test was used to evaluate the executive function, cognitive flexibility, inhibition ability, and attention deficits in many neurological disorders (28, 29). The numbers of correct answers, errors, reaction time and interference are the criteria for scoring. Recently, the test was used and standardized among Iranian bilingual population (30).

The software version of Persian Victoria Sroop Color Word test (31) and a lap top computer with 14" LCD monitor were used. In the first stage that lasted 45 seconds participants were asked to choose the color of the 16 circle shown on the screen in blue, red, yellow and green. Answers could be selected by V, B, N, M keys on the keyboard covered by blue, red, yellow and green, respectively. In this first stage, we aimed to test and practice the color perception and place of keys. For testing the participants' understanding of the purpose of test, the first stage was followed by another preliminary trial that lasted 45 seconds. Eight congruent and eight incongruent color names were presented on screen and the participant's had to identify the color and not the meaning of the words. The scores of this stage were not involved in the analysis. In the next step, 48 congruent and 48 incongruent chromatic words were presented randomly. Each word was presented for two seconds on the screen with 0.8 seconds intervals. In a real-time analysis manner, the software measures total time, mean reaction times, and numbers of no response, correct, and incorrect (errors) answers for congruent and incongruent color names, separately.

Finally, all data were analyzed using SPSS software, Version 20. The recovery rate according to sex, age, and the family history of stuttering was investigated using Chi-square and Fisher's exact tests. The scores of the two groups in the Purdue Pegboard and Stroop Word Color Tests were analyzed by independent and paired sample t, Mann-Whitney U and Wilcoxon tests. A logistic regression model was employed to determine the factors that could predict recovery from stuttering.

Results

Twenty-two children aged 7-14 years with a mean±SD age of 9.2±1.79 years were followed from 2007 to 2013. According to the result of the Edinburgh Handedness Inventory, only two participants in the persistent group were ambidextrous and all others in both groups were right handed. After the-six-year follow-up, five (22.7%) of the 22 participants had recovered from stuttering. However, the rate of recovery for the girls was slightly higher than boys ($p = 0.309$; Figure 1).

Four of the five recovered children and 16 of the persistent participants reported a family history of stuttering ($p = 0.41$; Figure 2). Overall, only two out of the 22 participants did not have a family history of stuttering. In order to compare the age-related recovery rate, the participants were divided into two separate age groups (7-10 and 11-14 year-olds). No significant difference was observed in the recovery rate between the two age groups ($p = 0.675$, Fisher's exact test).

Among Purdue Pegboard subtests, only the scores of the left hand in the persistent group was significantly higher than the recovered group ($p = 0.00954$) and the differences in the other subtests were not significant. Because the difference in left hand scores between the two groups might have been attributed to the two ambidextrous participants in the persistent group, they were omitted from data, and comparisons were performed again. Significant statistical differences were also found between the two groups after repeating the analysis ($p = 0.00933$). On the other hand, the right hand scores of the recovered group were significantly higher than their left hand scores ($p = 0.032$). However, the same result were not obtained in the persistent group ($p = 0.455$). The two groups differed significantly in the handedness index ($p = 0.005$; Table 1).

Stroop effect (Interference Effect) scores between the recovered (=1) and persistent (=1.24) groups did not differ significantly. The subtests of the congruent part of the Stroop Color-Word Test did not differ significantly between the two groups. The same results were also observed for the incongruent parts (Table 2).

Nevertheless, when the function of each group in congruent and incongruent steps was compared, significant differences were found between these two steps in the persistent group, but not in the recovered group in all five subtests (Table 3). We found that the function of the persistent group in congruent steps was significantly better than incongruent steps ($p<0.05$; Table 3).

The predictor variables including sex, family history of stuttering, age, interference effect, scores of assembly subtest of Purdue Pegboard and handedness index were entered into a logistic regression using enter and then forward stepwise model. According to the results of the enter model, none of the variables could predict the recovery/persistency from stuttering significantly. However, a good fit was observed between observed and predicted conditions. The model correctly classified 100% of the persistent or recovered cases and had a good sensitivity and specificity. The -2 log-likelihood (-2LL) statistic was 0.000, Cox and Snell R2 was 0.658 and Nagelkerke R2 was 1.00, all confirming a good fit of the model to the data. Using the forward stepwise model, the handedness index was a significant predictor of recovery from/persistency of stuttering ($p = 0.022$; Table 4). Handedness index could predict the recovery from or persistency of stuttering with 94% sensitivity and 84% specificity. Results from the logistic regression model indicated that a unit increase in handedness index increased the chance of recovery more accurately.

Table1: Comparison of the Purdue Pegboard Subtests scores between the recovered from and persistent to stuttering groups

Groups		Recovered	Persistent	P value
Purdue Pegboard Subtests	Right hand	14.4±0.89	14.5±1.5	0.858
	Left hand	12.8±0.44	14.35±1.16	0.00954
	P value	0.016	0.455	
	Handedness Index	1.1256±0.0704	1.0125±0.0695	0.005
	Assembly	26.6±6	27.47±3.28	0.673

Table2: Comparison of Stroop Color Words Subtests between the recovered from and persistent to stuttering groups

Stroop Test	subtests	Recovered	Persistent	P-value
Congruent	Total time (s)	45.8 ± 3.96	46.82 ± 6.45	0.742
	errors	0.2 ± 0.44	0.35±0.78	0.685
	Non- respond	0	0.18±0.39	0.335
	Correct response	47.8±0.44	47.47±0.87	0.432
	Reaction time (ms)	968±81	983±33	0.811
Incongruent	Total time (s)	47.6 ± 5.72	49.18±6.63	0.637
	errors	0.4±0.54	0.94±1.14	0.324
	Non- respond	0.8±1.09	0.82±1.33	0.972
	Correct response	46.8±0.83	46.26±1.78	0.507
	Reaction time (ms)	982±98	1017±127	0.580

Table 3: Comparison of Stroop Subtests scores between Congruent and Incongruent parts in the recovered from and persistent to stuttering groups

Groups	Subtests	Congruent	Incongruent	p-value
Recovered	Total time (s)	45.8 ± 3.96	47.6 ± 5.72	0.105
	Errors	0.2 ± 0.44	0.4 ± 0.54	0.374
	Non- responded	0	0.8 ± 1.09	0.178
	Correct response	47.8 ± 0.44	46.8 ± 0.83	0.089
	Reaction time (ms)	968 ± 81	982 ± 98	0.161
Persistent	Total time(s)	46.82 ± 6.45	49.18 ± 6.63	0.000
	Errors	0.35 ± 0.78	0.94 ± 1.14	0.039
	Non-responded	0.18 ± 0.39	0.82 ± 1.33	0.031
	Correct response	47.47 ± 0.87	46.26 ± 1.78	0.007
	Reaction time (ms)	983 ± 33	1017 ± 127	0.003

Table 4: Logistic regression analysis of the relationship between predictive variables and late recovery from stuttering using Forward Stepwise Model

Variable	LL	-2LL	Sig of -2LL	OR	CI	P-value
Handedness Index (HI)	-12.658	11.020	0.001	4.038E11	48.519-3.360E21	0.022

Fig1: recovery from stuttering in male/female

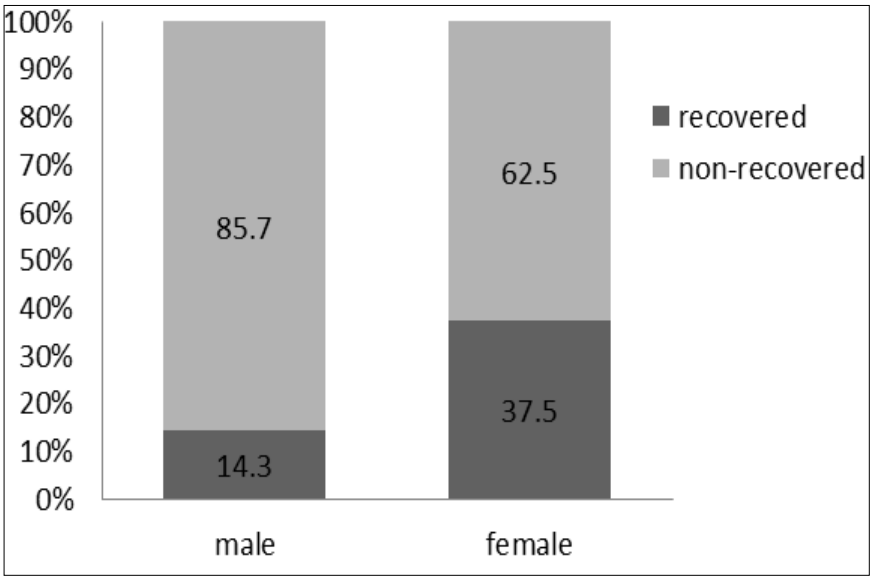
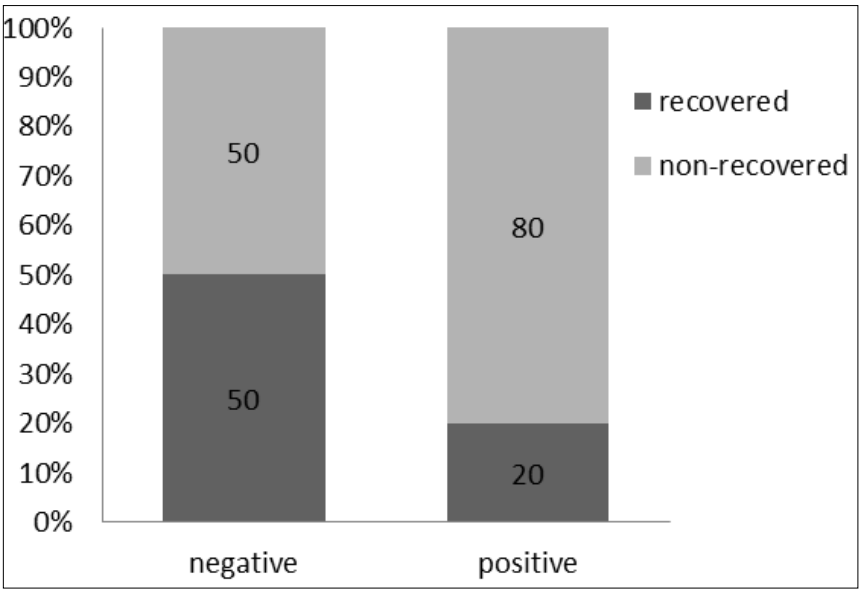


Fig 2: Late recovery from stuttering in subjects with negative / positive history of stuttering in their family



Discussion

In the present study, the rate of recovery from stuttering among Kurdish-Persian bilingual children who stuttered was investigated during a six-year period. All the participants were Kurdish-Persian bilinguals who were diagnosed as stutterers between the ages of 7 and 14. Data showed that only two participants received speech therapy intervention for a short time, but they were not diagnosed as recovered in the final evaluation. Therefore, the rate of recovery in the present study was investigated with respect to spontaneous or without formal intervention recovery. Five (22.7%) of the 22 children who stuttered had recovered.

The recovery rate from stuttering in the present study was lower than other studies on younger children. Yairi and Ambrose reported a 74% recovery among 2-5 year-old children who stuttered (32). In a six-year follow-up study on 23 participants with parental history of stuttering who were in the initial stage of the disorder and by using parent indication method, Kloth and colleagues reported a 70% recovery rate (33). Some other studies that explored the rate of recovery 2 to 5 years after the onset reported 68% to 80% recovery from stuttering (5, 34-36). This discrepancy is consistent with the view that greatest recovery occurs when children are younger. Contrary to studies on younger children, in a 10-year follow-up of children aged 7-9 years who stuttered through their teenage years, Fritzell (1976) (cited by Yairi & Ambrose, 2013) reported a recovery rate of 47% (32). Howell et al. reported a recovery rate of about 50% after four years follow-up of 76 eight-year-old children who stuttered (7). All these studies were conducted on monolingual population; however, similar to our study, Howell et al. reported a 25% recovery rate from stuttering among 8-10 year-old bilinguals from birth after four years of follow-up. They found that the recovery rate of bilingual children who stuttered was significantly lower than monolinguals and bilinguals that learned English as a second language at school (22). Considering that they merged the bilinguals that learned English as a second language at school and monolinguals because of the low numbers in the former group, when these speakers were divided into persistent and recovered cases, it was impossible to compare the recovery rate in bilinguals that learned English as a second language at school and the bilingual children who stuttered in this study. Nevertheless, as the only study that investigated the recovery from stuttering among bilinguals, and based on the similarity of age range between our study and theirs, it is probable that bilingualism has a negative effect on the chance of recovery.

The chance of recovery was neither dependent on the family history of stuttering nor on age and sex. These results are in agreement with several previous studies (7, 8). Studies, which investigated younger participants, showed that persistent children who stutter had more stuttering relatives in their families (37, 5). However, some researcher argued that the family history of stuttering probably is not a risk factor for persistency in older people who stutter (7, 38). Logistic regression models also indicated that hand fine motor control (assembly subtest of Purdue Pegboard test) and interference effect could not significantly predict recovery from stuttering. Among the risk factors investigated here, only handedness index could predict the recovery from or persistency of stuttering with 94% sensitivity and 84% specificity. This finding reveals the importance of handedness and brain laterality in the development of stuttering.

Findings of Purdue Pegboard test revealed an interesting picture. In contrast to the recovered group, there was no significant difference between right and left hands for the persistent group in the Purdue Pegboard test and they did not show any asymmetry in performance between the two hands. Our findings confirm previous research suggesting that people who stutter have problems in complete laterality. In contrast to previous studies that reported subtle deficit in fine motor control of people who stutter (39, 40), we found no significant difference between right hand and assembly subtest of Purdue Pegboard test and the persistent group performed the test as skillfully as the recovered. Likewise, some previous reports did not find any differences in speech movements between children who stutter and the control group (41). In a recent study, no significant difference was found between the children who stuttered and those who did not in terms of the acoustic patterns they produced in the diadochokinesis tasks (42). Some other researchers reported different results and found that people who stutter exhibited longer finger reaction time compared to normal subjects. It has been suggested that some people who stutter may have difficulty in the consistent execution of motor control strategies common to both speech and non-speech movements (43). Slower finger and vocal reaction time were also reported by other researchers (44). In contrast to these reports, our recovered and persistent groups had similar performance in terms of reaction time of both congruent and incongruent trials of the Stroop Color Word Test.

With respect to the Stroop Color Word Test, although the recovered group performed both congruent and incongruent trials better than the persistent group, there was no significant difference between the two groups in all subtests of the two trials. While the recovered group did the two trails of the test similarly, an interesting finding was the significant difference between congruent and incongruent trials in the persistent group. The result indicated that the persistent group obviously performed the incongruent trails slower and less proficiently than the congruent trails. Here the interference effect was revealed as an increase in reaction times, and the persistent group needed to

complete the incongruent compared to congruent trials (45). Slower reaction time in doing incongruent trails may reflect the interference effect in the persistent group and indicate that they need more time to inhibit habitual responses. However, we found no significant differences between recovered and persistent groups in the interference effect, which could be attributed to the small sample size. These findings indicate the probable role of inhibition control in the occurrence of stuttering. It has been reported that inhibitory control is a necessary factor for successful task performance and plays an important role in the self-regulation of emotional states (46) and coordination and integration of mental processes (47). Previous investigations also showed that children who stuttered had lower ability in inhibitory control when doing the GO/NoGo task (11). And the last but not the least is the fact that most differences in fine motor skills and inhibition control were reported in studies comparing people who stutter with a normal control group.

Limitations

Our study had some limitations. We had no normal control group. Moreover, the small sample size and its further decline due to inaccessibility should be taken into account in interpreting the results. Future studies could be done on the role of fine motor control, brain laterality and inhibitory control by elaborate longitudinal studies on a larger sample using accurate neuropsychological tests.

Conclusion

In children who stutter, the rate of recovery from stuttering for the bilinguals may be lower than the monolinguals. The chance of recovery neither depended on the family history of stuttering nor on the age and sex of the participants. In terms of handedness, hand motor control and inhibition, no significant difference was found between recovered and persistent groups except for left hand function that was higher in the persistent group. The handedness index that was obtained from dividing the motor function of right to left hand, could predict the recovery from stuttering significantly and accurately. The persistent group may have problems in hand function asymmetry and inhibitory control.

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Conflict of interest

The authors have no conflict of interest, no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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