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# Comparative Study of Vestibular Dysfunction on Motor Abilities among Children with Hearing Impairment and Cochlear Implant

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**Abstract**

*The purpose of the study was to compare the Vestibular dysfunction on motor abilities among children with hearing impairment and cochlear implant. Total of 60 children (CI=30 & PHI=30) aged from 6 to 10 years were taken for this study. All the children were assessed on One Leg Standing test, Test of Gross Motor Developemt-2 (TGMD-2) and Berry Visual Motor Integration (Berry VMI). The result of the study was suggested that children with cochlear implant have vestibular dysfunction on motor abilities similar to those children without cochlear implant. Based on the findings of result in this study, vestibular dysfunction on motor abilities was affected in their motor performance and it was also observed in children with cochlear implant. This would give scope to the Occupational Therapist to intervene and improve the Vestibular function among the children with Cochlear Implant.*

**Keywords:** Profound Hearing Impairment (PHI), Cochlear Implant (CI), Vestibular dysfunction.



## Introduction

Hearing impairment is often defined in terms of communication deficit. Despite, this communication deficit is the major impediment; hearing impairment is associated with other physical deficit such as vestibular related impairments **(Pajor Anna& Siegel 2008). Rine et al 2011** also reported that progressive motor deficit in children with sensorineural hearing loss. **Wiegersma et al., 2007,** confirmed that deaf children were inferior both in general dynamic coordination and visual-motor coordination. Moreover, it is postulated that these deficits are related to damage to the vestibular system. It is also reported that hearing impaired children with concomitant vestibular dysfunction have sensory organization deficit and poor reading acuity. **Sharon et al., 2008** found that a significant proportion of children with profound sensorineural hearing loss requiring cochlear implantation and they were demonstrated abnormalities in static and dynamic balance. Most children with vestibular deficits develop walking ability; hence their problems are not noted. However, these children avoid outdoor games. **Finita Glory et al., 2o11** conducted study of an overview of motor skill performance and balance in hearing impaired children. Childhood hearing impairment is a common chronic condition that may have a major impact on acquisition of speech, social and physical development. The author was concluded that injury to the vestibular organs may result in accompanying balance and motor development disorders.

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**Alexandra De Kegel et al**., **2012** conducted study about the influence of a vestibular dysfunction on the motor development of hearing-impaired children. Cross-sectional study was done to the fifty-one typically developing children and 48 children with a unilateral (n = 9) or bilateral hearing impairment (n = 39) of more than 40 dB HL between 3 and 12 years were tested by the Movement Assessment Battery for Children–Second Edition (M ABC-2), clinical balance tests, posturography, rotatory chair testing, and vestibular evoked myogenic potential (VEMP).The author was concluded that the hearing-impaired children are at risk for balance deficits. A combination of rotatory chair testing and VEMP testing can predict the balance performance.

**Jennifer B. Christy et al., 2014** conducted study about Reliability and Diagnostic Accuracy of Clinical Tests of Vestibular Function for Children. Twenty children with severe to profound bilateral sensorineural hearing loss and 23 children with typical development, aged 6 to 12 years, participated. The Head Thrust Test, Emory Clinical Vestibular Chair Test, Bucket Test, Dynamic Visual Acuity, Modified Clinical Test of Sensory Interaction on Balance, and Sensory Organization Test were completed twice for reliability. The result of the Clinical tests was concluded that the children with hearing impaired have vestibular dysfunction.

**Meredith Gronski et al., 2013**, conducted a study in Balance and Motor Deficits and the Role of Occupational Therapy in Children Who Are Deaf and

Hard of Hearing. The objective of this review is to analyze the literature regarding vestibular function, postural control and balance, and motor skills in children who are hearing impairment to determine the role for occupational therapy. The author was concluded that the children were demonstrated reduce levels of function in postural control, balance, and motor skills.

**Leen Maes al., 2014**, had done study in the Association between Vestibular Function and Motor Performance in Hearing-impaired Children. It was a Prospective study and conducted in Tertiary referral center. Thirty-six children (mean age, 7.5 years; range, 3.8 years –12.11 years divided into three groups: Normal Hearing children with normal vestibular responses, HI children with normal vestibular responses, and HI children with abnormal vestibular function. A vestibular test protocol (rotatory and collic vestibular evoked myogenic potential testing) in combination with three clinical balance tests (balance beam walking, one-leg hopping, one-leg stance). The author was concluded that an association between vestibular function and motor performance in HI children, with a more distinct motor deterioration if a vestibular impairment is superimposed to the auditory dysfunction.

**Venkadesan et al.**, **2012**.conducted a preliminary randomized controlled study on the effectiveness of vestibular specific neuromuscular training in children with hearing impairment. Twenty-three children with mean age of 7.5–8.1 years with hearing impairment were randomized to either the intervention or the control group. Measurement of motor skills (Test of Gross Motor Development-2), postural control (Pediatric Reach Test, One Leg Standing Balance Test and postural sway meter) and health related quality of life (PedsQL Generic Core Scale).The author was concluded that vestibular-specific neuromuscular training programme may improve the motor skills, balance and health-related quality of life in children with hearing impairment.

**Sneha et al., 2012** studied in Multisensory processing in children with cochlear implants. The objective of the study was to investigate the functions of the vestibular, tactile, visual, and proprioceptive modalities in children with prelinguistic hearing loss. Twelve children between the ages of 5.1 years and 8.11 years with bilateral severe-profound hearing loss participated in the study. All children used bilateral cochlear implants. Subtests of two norm-referenced instruments, the Sensory Integration and Praxis Test and the Beery Test of Visual-Motor Integration, were administered to all of the children. The author was concluded that the majority of children demonstrated vestibular dysfunction

Results of the recent investigation have revealed that children with hearing loss may also present with balance and / motor deficits **(Rine RM,et al 2010).** Moreover, a recent systematic review confirms that balance and motor impairments were associated with hearing impairment (**Rajendran, 2010)**. Based on the research evidence, the main aim of the present study was to compare the vestibular dysfunction on motor abilities among children with hearing impairment and cochlear implant.

**Aim of the study**

1. To compare the vestibular dysfunction on motor abilities among children with hearing impairment and cochlear implant

**Method**

**Participant**

The present quantitative study was to compare the means between two independent groups and it was conducted on hearing impaired children with cochlear implant (n=30) and without cochlear implant (n=30) studying in schools for hearing impairment in Chennai. The sample was selected through Non- probability convenient sampling procedure with the age group of 6 to 10 years

**Inclusion criteria**

- Children with cochlear implant
- Children with Profound Hearing Impairment (without cochlear Implant>90db)
- Ability to understand simple instruction
- Ability to stand and walk independently

**Exclusion criteria**

- Associated cognitive, physical and visual impairments
- Neurological, orthopaedic and cardiovascular condition

**Instruments Used**

**1. One leg standing test**

The one leg standing test was used to assess standing balance of the child. Instruction was given to the child to stand on one leg for as long as possible. Before the test the demonstration was given by using chair/ table/ counter for initial support. Start timing when hand leaves the chair/table (if child are not using a support, start when the foot is lifted) and Stop timing when their free foot touches the ground, their hand contacts the chair/table, their foot moved, or 30 seconds has passed. Record the time to a tenth of a second. Cut point >10 seconds indicated good balance, 5-10 seconds indicate balance impairment and less than 5 seconds fall risk.

**2. Test of Gross Motor Development-2 (TGMD-2)**

The Test of Gross Motor Development – 2 (TGMD-2) is a standardized test that measures gross motor abilities in children aged 3 through 10 years. The test takes 15-20 minutes to administer per child. Set up and clean-up may take an additional 10 minutes. The TGMD-2 looks at 12 gross motor skills divided into two subtests: 1) Locomotor (run, hop, gallop, leap, horizontal jump, and slide). 2) Object Control (ball skills such as striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll). The child is given 1 for a pass, 0 for a failed attempt. There are no partial marks. Add the two trials together to get the total Score for each performance criteria. Add the total scores for each criterion to get the Skill Score. At the end of each Subtest (Locomotor and Object Control) add up the 6 skill scores to get the Subtest Raw Score. High scores indicate better performance than low scores.

**3. Beery Visual Motor Integration (BVMI)**

The Berry VMI and its two supplemental standardized tests, Visual Perception and Motor Coordination, provide the most valid and economical visual-motor screening battery available for preschool to adult ages. The Beery VMI is a developmental sequence of geometric forms to be limited or copied with paper and pencil. The 30- item Berry VMI full form for ages 2 through 18 can be group or individually administrated in about 10 to 15 minutes. Visual perception test, the first three items require very young children to identify parts of their own bodies, picture outlines, and parts of a picture. For the remaining 27 items, one geometric form that is exactly the same as each stimulus is to be chosen from among others that are not exactly the same as the stimulus. During a three minute period, the task is to identify the exact match for as many of the 27 stimuli as possible.

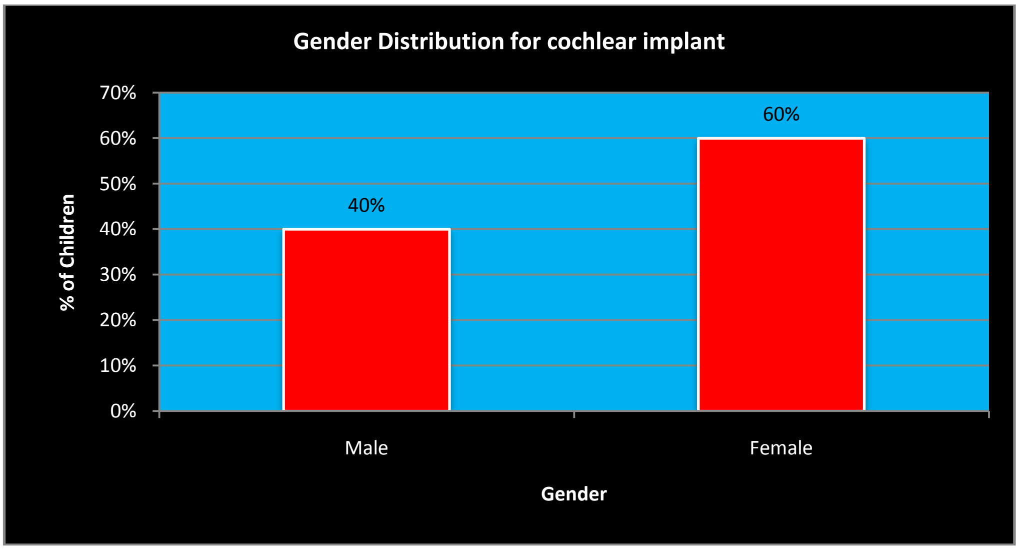
**Procedure**

In this research, the purpose of the study was explained to the authorities of the schools involved and informed consent was obtained from parents. The sixty children were recruited for this study and the samples were selected through medical reports and diagnosis of hearing impairment. The test was conducted by using One leg standing test, Test of Gross Motor Development-2 and Beery VMI to children with cochlear implant and without cochlear implant and their scores were recorded. Data were analysed and the means for survey items were determined and displayed in tabular and graphic formats.

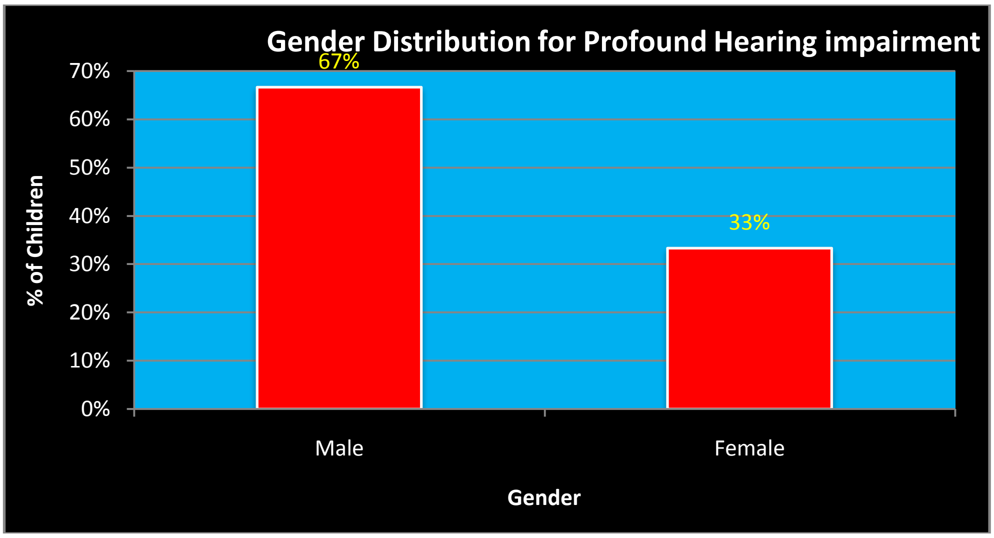
**Result and discussion**

Children with hearing impairment are a significant public health problem, which is associated with long-term academic and communicative difficulties. Besides this communication deficit, which is a major impediment, hearing impairment is also associated with other physical deficits such as vestibular- related impairments. (Pajor, 2008). Childhood deafness often causes psycho- intellectual and social developmental disorders in children because they have difficulty interacting with their surroundings (Roy 2010). A recent systematic review has also shown that children with hearing impairment have associated with vestibular-related impairments and diminished health-related quality of life ((Rajendran 2012).

**Graph I.** Comparison of gender difference in Cochlear implant children



**Graph II.** Gender Distribution for Profound Hearing impairment




The aim of the study was to compare the vestibular dysfunction on motor abilities among children with hearing impairment and cochlear implant. The result have been analysed in various components of motor performance in CI & PHI and also to compare between male and female. Graph: I showed the statistics for age and gender, the average age of the 30 subjects from the cochlear implant is 7.07 years with the standard deviation of 0.94 years, while the graph-II showed the average of 30 subjects from the profound hearing impairment is 6.83 years with the standard deviation of 0.70. It Showed that 40% male and 60% female in children with cochlear implant and 67% male and 33% female in children with profound hearing impairment (without cochlear implant).

**Table I.** Shows the value of comparison of one leg standing test scores

| Variable | Numbers | Mean (Second) | Std deviation |
|---|---|---|---|
| Cochlear implant (CI) | 30 | 6.57 | 1.61 |
| Profound hearing impairment (PHI) | 30 | 6.30 | 1.29 |

Table I showed the value of comparison one leg standing test score of both the group of children. The cochlear implant children mean test score is 6.57 seconds and the profound hearing impairment children mean test score is 6.30. The cut of point of one leg test score was indicate that the presence of balance impairment in both the group of children. The present result supports the previous study done by **Gheysen F et al., 2008** that the motor Development of Deaf Children With and Without Cochlear Implants, there was a deficit in balance and motor skills of children with cochlear implant.

**Table II.** Shows the comparison of TGMD and BVMI test score of cochlear implant children and without cochlear implant

| Variables | | Number | Means (developmental age score) | Std. Deviation |
|---|---|---|---|---|
| TGMD-2 | Locomotor | CI | 3.00 | 0.00 |
| | | PHI | 3.00 | 0.00 |
| | Object control | CI | 3.28 | 0.23 |
| | | PHI | 3.13 | 0.26 |
| BVMI | | CI | 3.22 | 0.16 |
| | | PHI | 3.23 | 0.36 |

Note: TGMD-2 (Test of gross Motor Development-2), BVMI (Beery Visual Motor Integration), CI (Cochlear Implant), PHI (Profound Hearing Impairment)

Table II showed the value of comparison of developmental age of mean score of both the group. The result of the study was indicated that the presence of child's motor development was 3years of age in both the group of children. The result also supported by **Christopher et al., 2011** conducted study about Non verbal Cognition in Deaf Children Following Cochlear Implantation: Motor Sequencing Disturbances Mediate Language Delays. The author was revealed that the children with Cochlear Implant showed disturbances solely on motor sequencing. The present study showed that the vestibular dysfunction on motor abilities was not given any differences in both the group of children. The cochlear implant children also showed deficit in their motor performance in this study.

**Conclusion**

The present study concluded that the vestibular dysfunction on motor abilities was observed among children with cochlear implant. This would give better scope of Occupational Therapist to intervene and improve the Vestibular function among children with Cochlear implant.

**Implication of the study**

Occupational Therapy intervention can be given to cochlear implant children in the area of motor development and balance skills

**Limitation of the study**

1. Small sample size and convenient sampling procedure.
2. The study was conducted on limited age range

**Recommendation**

The children needed demonstration through displaying the videos, pictures before or during the assessment to cochlear implant and profound hearing impairment in future studies.

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**Appendix I.** Test of Gross Motor Development-2

Section VI. Subtest Performance Record

Preferred Hand: Right ☐ Left ☐ Not Established ☐
Preferred Foot: Right ☐ Left ☐ Not Established ☐

**Locomotor Subtest**

| Skill | Materials | Directions | Performance Criteria | Trial 1 | Trial 2 | Score |
|---|---|---|---|---|---|---|
| 1. Run | 60 feet of clear space, and two cones | Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial. | 1. Arms move in opposition to legs, elbows bent | | | |
| | | | 2. Brief period where both feet are off the ground | | | |
| | | | 3. Narrow foot placement landing on heel or toe (i.e., not flat footed) | | | |
| | | | 4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks) | | | |
| | | | | | Skill Score | |
| 2. Gallop | 25 feet of clear space, and tape or two cones | Mark off a distance of 25 feet with two cones or tape. Tell the child to gallop from one cone to the other. Repeat a second trial by galloping back to the original cone. | 1. Arms bent and lifted to waist level at takeoff | | | |
| | | | 2. A step forward with the lead foot followed by a step with the trailing foot to a position adjacent to or behind the lead foot | | | |
| | | | 3. Brief period when both feet are off the floor | | | |
| | | | 4. Maintains a rhythmic pattern for four consecutive gallops | | | |
| | | | | | Skill Score | |
| 3. Hop | A minimum of 15 feet of clear space | Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial. | 1. Nonsupport leg swings forward in pendular fashion to produce force | | | |
| | | | 2. Foot of nonsupport leg remains behind body | | | |
| | | | 3. Arms flexed and swing forward to produce force | | | |
| | | | 4. Takes off and lands three consecutive times on preferred foot | | | |
| | | | 5. Takes off and lands three consecutive times on nonpreferred foot | | | |
| | | | | | Skill Score | |
| 4. Leap | A minimum of 20 feet of clear space, a beanbag, and tape | Place a beanbag on the floor. Attach a piece of tape on the floor so it is parallel to and 10 feet away from the beanbag. Have the child stand on the tape and run up and leap over the beanbag. Repeat a second trial. | 1. Take off on one foot and land on the opposite foot | | | |
| | | | 2. A period where both feet are off the ground longer than running | | | |
| | | | 3. Forward reach with the arm opposite the lead foot | | | |
| | | | | | Skill Score | |

| Skill | Materials | Directions | Performance Criteria | Trial 1 | Trial 2 | Score |
|---|---|---|---|---|---|---|
| 5. Horizontal Jump | A minimum of 10 feet of clear space and tape | Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial. | 1. Preparatory movement includes flexion of both knees with arms extended behind body | | | |
| | | | 2. Arms extend forcefully forward and upward reaching full extension above the head | | | |
| | | | 3. Take off and land on both feet simultaneously | | | |
| | | | 4. Arms are thrust downward during landing | | | |
| | | | | | Skill Score | |
| 6. Slide | A minimum of 25 feet of clear space, a straight line, and two cones | Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial. | 1. Body turned sideways so shoulders are aligned with the line on the floor | | | |
| | | | 2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot | | | |
| | | | 3. A minimum of four continuous step-slide cycles to the right | | | |
| | | | 4. A minimum of four continuous step-slide cycles to the left | | | |
| | | | | | Skill Score | |
| | | | Locomotor Subtest Raw Score (sum of the 6 skill scores) | | | |

**Object Control Subtest**

| Skill | Materials | Directions | Performance Criteria | Trial 1 | Trial 2 | Score |
|---|---|---|---|---|---|---|
| 1. Striking a Stationary Ball | A 4-inch lightweight ball, a plastic bat, and a batting tee | Place the ball on the batting tee at the child's belt level. Tell the child to hit the ball hard. Repeat a second trial. | 1. Dominant hand grips bat above nondominant hand | | | |
| | | | 2. Nonpreferred side of body faces the imaginary tosser with feet parallel | | | |
| | | | 3. Hip and shoulder rotation during swing | | | |
| | | | 4. Transfers body weight to front foot | | | |
| | | | 5. Bat contacts ball | | | |
| | | | | | Skill Score | |
| 2. Stationary Dribble | An 8- to 10-inch playground ball for children ages 3 to 5; a basketball for children ages 6 to 10; and a flat, hard surface | Tell the child to dribble the ball four times without moving his or her feet, using one hand, and then stop by catching the ball. Repeat a second trial. | 1. Contacts ball with one hand at about belt level | | | |
| | | | 2. Pushes ball with fingertips (not a slap) | | | |
| | | | 3. Ball contacts surface in front of or to the outside of foot on the preferred side | | | |
| | | | 4. Maintains control of ball for four consecutive bounces without having to move the feet to retrieve it | | | |
| | | | | | Skill Score | |

**Appendix III, Mater chart-Children with Cochlear Implant**

| | age | sex | One leg | TGMD | | | | BVMI | |
|---|---|---|---|---|---|---|---|---|---|
| sl.no | | | seconds | loc.score | age score | obj.score | age score | BVM. | age score |
| 1 | 9y11 | F | 7 | 1 | <3-0 | 1 | <3-0 | 45 | 3.3 |
| 2 | 7y1 | F | 5 | 2 | <3-0 | 2 | 3 | 53 | 3.6 |
| 3 | 7y4 | F | 6 | 1 | <3-0 | 2 | 3.3 | 48 | 3.3 |
| 4 | 8y2 | M | 9 | 1 | <3-0 | 1 | <3-0 | 45 | 3.3 |
| 5 | 8y4 | M | 8 | 1 | <3-0 | 1 | <3-0 | 45 | 3.3 |
| 6 | 7y4 | M | 5 | 1 | <3-0 | 1 | <3-0 | 51 | 3.6 |
| 7 | 7y8 | F | 3 | 1 | <3-0 | 2 | 3.9 | 45 | 3.1 |
| 8 | 7y1 | F | 6 | 2 | <3-0 | 3 | <3-0 | 45 | 3.1 |
| 9 | 6y10 | M | 5 | 2 | <3-0 | 2 | <3-0 | 48 | 3.3 |
| 10 | 8y1 | F | 8 | 1 | <3-0 | 1 | 3.3 | 49 | 3.6 |
| 11 | 9y | F | 9 | 1 | 3 | 1 | 3 | 45 | 3.1 |
| 12 | 6y6 | F | 8 | 2 | <3-0 | 3 | 3 | 45 | 3.1 |
| 13 | 6y7 | F | 6 | 2 | <3-0 | 3 | 3 | 45 | 3.1 |
| 14 | 6y | F | 7 | 3 | <3-0 | 3 | <3-0 | 45 | 3.1 |
| 15 | 9y | M | 9 | 1 | <3-0 | 1 | <3-0 | 45 | 3.3 |
| 16 | 6y1 | F | 5 | 2 | <3-0 | 3 | <3-0 | 45 | 3.1 |
| 17 | 7y6 | F | 4 | 1 | <3-0 | 2 | 3.3 | 45 | 3.1 |
| 18 | 6y9 | M | 7 | 2 | <3-0 | 2 | <3-0 | 45 | 3.1 |
| 19 | 7y10 | M | 7 | 1 | <3-0 | 1 | <3-0 | 45 | 3.1 |
| 20 | 7y4 | F | 5 | 2 | <3-0 | 3 | 3.3 | 45 | 3.1 |
| 21 | 6y3 | M | 9 | 3 | <3-0 | 3 | <3-0 | 49 | 3.1 |
| 22 | 8y3 | F | 6 | 1 | <3-0 | 1 | 3 | 45 | 3.3 |
| 23 | 7y6 | M | 8 | 1 | <3-0 | 1 | <3-0 | 45 | 3.1 |
| 24 | 7y4 | F | 5 | 2 | <3-0 | 3 | 3.3 | 45 | 3.1 |
| 25 | 6y5 | F | 6 | 3 | <3-0 | 3 | <3-0 | 51 | 3.3 |
| 26 | 7y3 | M | 5 | 1 | <3-0 | 1 | <3-0 | 45 | 3.1 |
| 27 | 7y5 | M | 7 | 2 | <3-0 | 3 | 3.6 | 46 | 3.3 |
| 28 | 6y8 | M | 6 | 2 | <3-0 | 2 | <3-0 | 49 | 3.3 |
| 29 | 8y2 | F | 8 | 1 | <3-0 | 1 | 3.6 | 45 | 3.3 |
| 30 | 7y5 | F | 8 | 1 | <3-0 | 3 | 3.3 | 45 | 3.1 |

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