Lip Trill Effects on Vocal Function, Vocal Pitch, and Harmonics-to-Noise Ratio: A Multiple Baseline Study of Three Vocally Healthy Females

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ABSTRACT

Background. The lip trill is a semi-occluded vocal tract exercise found to have positive outcomes on vocal parameters of healthy individuals after a single session. However, the effect of several lip trill sessions has not been studied.

Objective. This study investigated the effect of a 3- to 4-week lip trill exercise program on Maximum Phonation Time (MPT), Maximum Phonation Frequency Range (MPFR), Harmonics-to-Noise Ratio (HNR), and mean Speaking Fundamental Frequency (mean SFF).

Methods. Three vocally untrained healthy females with perceptually normal voices participated in a multiple-baseline, single-case experimental research. Five to seven direct training sessions were randomly assigned. Self-implementation was encouraged thereafter. Participants were assessed on all outcome measures for 15 sessions. Data were visualized and inspected. Cohen's d was also derived using Standardized Mean Difference for single-subject research.

Results. Visual and statistical analyses revealed a decreased MPT when training was introduced, increased MPFR variability during the training phase, and increased stability in mean SFF post-training. Perceived effects include vocal freedom, decreased laryngeal stress, and vocal conditioning. Vocal outcomes in one participant yielded a significant effect on MPFR and mean SFF and a small effect on HNR.

Conclusion. There is evidence of lip trill effect on pitch control and vocal conditioning. Findings also revealed that motivation, exercise frequency, and adherence could contribute to positive gains in vocally healthy speakers. Further investigation in consideration of the study findings and limitations is warranted.

Keywords: lip trill, prevention, vocal health promotion, acoustic vocal parameters, normal voice

INTRODUCTION

Heavy vocal demand is a risk to vocal health. Research suggests that developing voice-related concerns is greater among occupational voice users.[1-3] Thus, it can be considered a threat to health and safety in the workplace.[4-5] Depending on its severity, voice problems may cause absence from work, career change, and loss of income.[3] To prevent this, methods of voice care that can minimize or avoid the handicapping consequences of voice disorders must be studied.[6-9] Voice care programs may take an indirect, direct, or combined approach.[10] The indirect training approach emphasizes vocal education (vocal anatomy/physiology) and vocal hygiene (risks to vocal health, preventive vocal behaviors).[8,11-14] In contrast, the direct training approach promotes regular vocal exercise to keep the voice in the optimal state.[9-10] Most direct training components of voice programs utilize voice therapy

eISSN 2094-9278 (Online)
Published: May 29, 2023
https://doi.org/10.47895/amp.vi0.3913

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principles and techniques with evidence on feasibility for non-pathological voices that are still emerging. However, it must be considered that, since the direct training approach in voice care entails regular exercise for a prolonged period, potential vocal exercises must first be studied for their effects on the vocal pitch, loudness, and quality for a duration of use before it is recommended to the healthy population and further explored for their preventative value. Hence, there is a need to study the effects of each potential vocal exercise on a healthy voice.

The lip trill is a semi-occluded vocal tract exercise (SOVTE) with potential application in maintaining vocal health. Lip trills are among the most used SOVTEs with several documented positive effects on the voice.[15-21] It is recommended for vocal habilitation and rehabilitation.[19-24] Lip trills can be voiced or unvoiced. Voiceless lip trill is achieved by vibrating the lips upon expiration without vocal fold vibration. On the other hand, voiced lip trill requires the simultaneous vibration of the vocal folds and the lips. This lowers the degree of vocal fold adduction so that lesser pressure is used to oscillate the vocal folds.[18] Such phenomena lower the phonation threshold pressure, reducing the amplitude of vocal fold movement and collision needed for each acoustic output level.[25,26] As a result, the voice is produced with minimal vocal fold contact, while the desired vocal loudness is produced with decreased vocal effort.[27] The vibrations in the entire vocal tract due to strong coupling during lip trills also have a massage-like effect on the vocal folds.[28]

Some studies were conducted to explore vocal adduction, vocal economy, aerodynamic ability, and acoustic vocal parameters of vocally healthy individuals after lip trills.[15-18,29] Most of these studies investigated the after-effects in a single session.[15-16,18] Gaskill & Erickson conducted a study on the estimated closed glottal quotient following the use of lip trill on 25 males without a history of dysphonia using electroglottography.[18] The findings showed a decrease in vocal fold closed quotient, indicating reduced vocal fold adduction on the same task after lip trill, with a more pronounced change among participants without vocal training. Calvache et al. observed an increase in Quasi-Output Cost Ratio (QOCR) – a measure of the vocal economy – after 36 participants performed lip trills.[16] The authors concluded that SOVTE – including lip trill – can positively affect the vocal economy of both healthy subjects and subjects with dysphonia. Brockmann-Bauser et al. conducted a study to determine the effects of a lip trill protocol on 25 vocally healthy women between 19 to 58 years old over a single lip trill session.[15] The lip trill protocol was created considering the recommendations of Menezes et al. to restrict the total cumulative lip trilling to 3 minutes for females to avoid vocal discomfort.[30] The study revealed significant improvements in fundamental frequency and vocal intensity. The authors recommended investigating a prolonged training scheme to identify if these findings transfer to long-term effects and habitual speech patterns.

Specific to a particular group of occupational voice users, positive lip trill effects on ease of singing and vocal parameters were seen among singers.[29,31] Dargin compared the effects of lip trill and straw phonation on the perceived ease of singing and singing voice handicap among professionally trained singers.[31] Although singing voice handicap results did not reveal any significant effect, the singer's ease of singing improved after three weeks for lip trill and straw phonation groups. In another study, Lee et al. explored the effect of a Modified Voiced Lip Trill Training (MVoLT) on the vocal changes of 32 musical singing theater students using a systematic program for three months.[29] The authors found increased maximum phonation time, subglottal pressure, and mean airflow rate. Furthermore, decreased psychometric measures, higher maximum pitch, and increased vocal range were noted. The authors concluded that the MVoLT is a potentially effective and safe vocal training exercise in musical theater singing.

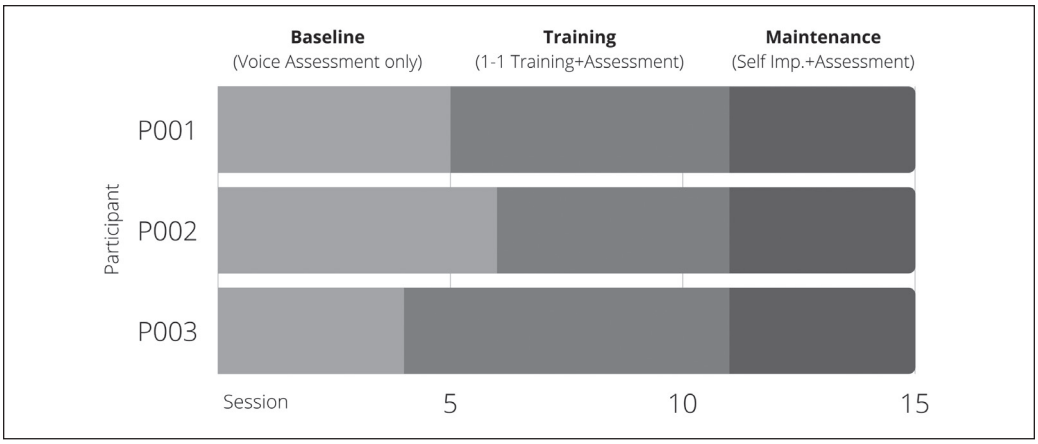
Thus, while it is effective on pathological voices, the lip trill can also create positive outcomes for vocally healthy individuals. Lip trill effects over time must be studied to provide evidence of viability for repeated and prolonged use. Hence, this study studied the effects of a lip trill exercise protocol on the vocal parameters of 3 vocally healthy cisgender females over the course of 3- to 4- weeks of regular use. Specifically, we investigated the following question: "Will the lip trill exercise increase the Maximum Phonation Time (MPT), Maximum Phonation Frequency Range (MPFR), Harmonics-to-Noise Ratio (HNR), and Speaking Fundamental Frequency (SFF) of three vocally untrained female occupational voice users after 3- to 4- weeks of regular use?" The study focused on cisgender females and excluded males and transgender females to eliminate possible confounding factors associated with differences in laryngeal anatomy and vocal exercise length.[30]

METHODS

Research Design

Multiple baselines across subjects-single case experimental designs were utilized. MBD is a single-case experimental design used to determine causal relationships between the independent and dependent variables through a thorough investigation of identified outcome measures. It is cost-effective to pilot a known intervention for a different type of patient.[32] In addition, it eliminates the need to remove the intervention that may be working for the subjects.[32-34] Repeated measurements were done to investigate the changes in the outcome measures, with the participants themselves providing their control data.[32,33] The involvement of at least three subjects and the randomization of the number of baseline measures and training sessions were done to increase the study's internal validity.[32]

The study was comprised of baseline and treatment phases (Figure 1). The baseline phase, which was before intro-



During Weeks 1-2, the participant is only met by the blinded external assessor (EA) for voice assessment only sessions. This is the baseline phase (light gray shade). In Weeks 2-4, the participant is met via telepractice by the principal investigator (PI) for vocal training followed by EA for assessment. This is the vocal training phase (medium gray shade). By Weeks 4-5, training sessions have ceased, and the participants were encouraged to continue the exercise. However, they still were attending voice assessment sessions with the EA. This is the post-training or maintenance phase (dark gray shade). The lip trill exercise was not discontinued after the training phase.

Figure 1. Assessment and training schedule.

ducing the lip trill exercise, was comprised of assessment-only sessions that aimed to collect participant baseline measurements for all outcome measures. On the other hand, the treatment phase involved direct instruction of the lip trill exercise protocol (vocal training phase) and self-implementation of the participants (maintenance phase). Assessment continued during the treatment phase after lip trill exercise sessions.

The study was given ethical approval by the University of the Philippines Manila Research Ethics Board (UPMREB) on January 15, 2021.

Sampling and Recruitment

The study utilized passive recruitment – a recruitment process wherein potential participants are provided information about the research and openly invited to participate.[35] Facebook, a widely used social media platform, was found suitable for online recruitment given the sample size, the non-clinical nature of participants, the telepractice mode of implementation, and the target age bracket.[36] A recruitment advertisement was shared daily on the Story feature for 12 days. This feature ensured that the messages were directly routed to the principal investigator's inbox. The following inclusion-exclusion criteria were used to select participants:

Inclusion Criteria

1. Female (cisgender) between 21 and 45 years old;
2. Able to perform the lip trill upon screening;
3. Acquired a zero (0) score on all vocal parameters in the consensus auditory evaluation of the Voice or CAPE-V;[37]
4. Cleared with oral peripheral mechanism examination;
5. Signified negative for upper respiratory tract infection, asthma, gastroesophageal reflux, and any vocal complaint on the day of initial screening;
6. Received no formal vocal coaching/education;
7. Should be a non-smoker.

Exclusion Criteria

1. Presence of any health condition that would limit the participant's ability to participate. Any symptom of illness excluded a prospective participant;
2. History of vocal fold growths (e.g., nodules, etc.) or diagnosis of any neurologic disease;
3. Lacks any of the required equipment or service: gadget for taking in Zoom calls, a voice recording device that passed quality screening, earphones, and internet connection;
4. Cannot commit to pre-scheduled online sessions on a thrice-a-week basis;
5. Situated in a place that has background noise that cannot be significantly reduced or controlled during the assessment;
6. Refusal to give informed consent.

A total of six (6) females expressed interest in joining. Three (3) did not qualify due to high ambient noise levels during sample voice recording and changes in personal schedule. The successful participants were then referred to as P001 (participant 1), P002 (participant 2), and P003 (participant 3) for the duration of the study. The participants' session order determined their participant number. The introduction of the lip trill was temporally staggered to see better whether the vocal parameters were affected when the intervention was introduced to the participants.[32,33,38,39]

Voice Outcome Measures

Four outcome measures determined the extent of lip trill effects on the participants' voices. MPT refers to the longest time an individual can sustain a vowel, usually /a/ or /i/, after a deep breath in a comfortable pitch. The measure reflects the individual's respiratory and phonatory function. The norm for MPT is 15-25 seconds for adults.[40] MPFR is the range of frequencies that an individual can phonate. The lowest and highest pitches were converted to the closest corresponding semitones following the values published on the web by Michigan Technological University.[41] The number of semitones between the lowest and highest frequencies were counted to obtain the MPFR.[42] The mean phonation frequency range for females is 3 octaves or 37 semitones or 139 Hz to 1108 Hz.[43] HNR measures the degree of acoustic periodicity of the voice, with a threshold at 20dB for sustained phonation or not lower than 7dB for healthy voice users.[40,44] Lastly, the mean SFF is the average frequency at which the person speaks. Normative values for the fundamental frequency range for females are 190-250 Hz.[40]

Voice Assessment

The assessment tasks comprised sustained phonation of /a/ to obtain MPT, pitch glide to determine the MPFR, and a speech sample of the Rainbow Passage to obtain HNR and SFF. Assessment procedures were carried out by an external assessor (EA) via telepractice using the Zoom video conferencing platform. The EA is a speech pathologist trained in acoustic voice assessment and a certified regular member of the local professional SLP organization. Before the first assessment session, the principal investigator (PI) and EA reviewed the selected voice assessment tasks, conducted a practice acoustic analysis, and discussed data entry using Google Forms. The EA measured each vocal parameter using the provided assessment procedures every session (15 sessions per participant). She was blinded from the study purpose and the participants' lip trill sessions with the PI.

In a separate session, both the EA and the participants were oriented on the standard mic positioning (i.e., microphone at the level of either the nose or the chin to prevent clipping and plosive bursts) and mouth-to-microphone distance (i.e., at least 6 inches or the distance between the elbow and shoulder when the arm is raised). The absence of any audible noise during pitch glide and rainbow passage tasks was emphasized, whereas audible noise prompted a repetition of the affected task. The participants were explicitly instructed not to perform the assessment tasks outside sessions.

The participants recorded themselves to capture their raw voices. The following devices were used: P001- Huawei Nova3i phone and its built-in voice recorder, P002- iPhone X and the voice memo application, and P003- Samson Q2 microphone and Audacity software. Recordings were sent to the PI using Viber, a messaging application with end-to-end encryption that allows files to be sent in their original size and quality. PI then converted the recording to a WAV file using Garageband for Mac software and uploaded these to a Google Drive folder that the EA could access.

The EA then performed acoustic analysis on these recordings using Praat Software v6.1.27. Praat is widely used in voice research and clinical analysis to generate voice reports on the voice samples' pitch, loudness, and harmonicity. The pitch setting was set to 75 Hz to 1300 Hz, encompassing the maximum female pitch range.[43] The software's default settings were used for the rest of the outcome measures. Finally, the data collection Google form was also discussed. The EA used this online form to submit measurements obtained from every assessment session (MPT, lowest fundamental frequency, highest fundamental frequency, HNR, SFF). Thus, all measurements were compiled through this method. Only the participant code (e.g., P001) and assessment date were used to identify the respondents and when the measurements were taken. The results were then exported as a table in a linked Google Sheet. AFTER THE LAST ASSESSMENT SESSION, the PI only viewed and generated this Google Sheet.

Vocal Training

The PI conducted Vocal training sessions via telepractice using the Zoom video conferencing platform. The protocol performed by Brockmann-Bauser et al.[15] was adapted and modified by adding sustained unvoiced lip trill and voiced lip trilled utterances (counting 11-20 and an expression for the day, e.g., "Good morning!") for this study to facilitate a carry-over of the lip trill effect into normal speaking. Visual cues following the modified "Voice Figures" accompanied the PI's instructions and were screen shared. Training occurred between Weeks 2 to 4. The number of training sessions was then randomly assigned to the participants using random.org/list.[28,33]

For the first few sessions, the part practice of the lip trill protocol was done. This gradually increased in length and number of tasks until the participant could perform the entire protocol. The pace of completing the protocol depended on the participant's ability to follow the modeling and instructions provided. Some verbal reminders had to be repeated throughout that pertain to lip closure tightness (i.e., relax the lips a little to allow it to vibrate), breathing enough (i.e., try filling the body with more air to sustain that trill), steady airflow (i.e., make the air vibrate the lips with the least possible force), correct pitch variations (i.e., listen carefully and watch my hands), and pace (i.e., let's try it a little bit slower). A water break was also given. Once the complete protocol was learned, the participants were encouraged to do the exercise on their own once a day, ideally before vocal demand at work. Each received an mp3 file containing the exercise sequence and instructions to enable self-implementation that as much as possible adheres to the training protocol. The vocal training sessions were done within 10 minutes.

Data Collection Procedure

During the baseline phase, the participants only attended EA voice assessment sessions. The participants attended PI vocal training and EA voice assessment sessions during the vocal training phase. Sessions lasted for approximately 20 minutes in this phase. The said training phase ended in session 11, and the maintenance phase commenced in session 12 for all participants. Voice assessment sessions with the EA continued until session 15. The EA also determined whether the participants were exercising their voice and on which days during this phase.

Intra-rater Reliability

Intra-rater reliability on the use of Praat in processing the voice samples was also performed. Practice voice samples were processed in Praat to obtain MPT, highest pitch, lowest pitch, HNR, and mean pitch. The EA was given two sets of voice samples on two separate days. Except for the length of the audio and the file name, the voice samples were the same for both days. Thus, the EA measured the same voice samples on separate occasions. EA's consistency in measurement was then determined by computing the percent difference between the two measurements using the formula: Percentage Difference = ((V1-V2)/((V1-V2)/2))*100. The computation resulted in a less than 3% average percentage difference, suggesting more than 97% similarity in the EA's submitted values (Table 1).

Data Analysis

The data was reorganized and then sent to the statistician for data visualization and statistical analysis. Line graphs were generated to visualize the results over time. Level, trend, and variability/stability were analyzed.[33,45,46] The mean level line shows the amount of performance change per phase, while the trend line shows the direction of change.[46] On the other hand, variability shows the stability or fluctuations of data.[45] The split-middle technique was used to obtain the trend line.[39]

Moreover, the degree of overlap was obtained where a 30% overlap is acceptable. If the degree of overlap exceeds this, then there is no functional relationship.[47] Lastly, the immediacy of effect where in immediate change between the last 3 data points to the first 3 data points of the next phase was inspected to support the presence of a functional relation further, if any.[46,47] Apart from analyzing each participant's graphs, between-participant analysis was done to compare tiers and find replication across participants' results. A functional relation between the lip trill and the outcome measure could be confidently established if the results were replicated.

To supplement the visual inspection, the results were also subjected to the Standardized Mean Difference measure of effect to quantify the outcomes and determine how much change was caused by an intervention.[32,38,48] Cohen's d was computed following the recommendation of Busk and Serlin as cited in Beeson & Robey for computing effect sizes in single-subject research.[48] The maintenance phase and the baseline phase measurements were compared in this order. Given our research question, the effect size (ES) should be more than zero to reject the null hypothesis. The ES can be *small* (d=.20), *medium* (d=0.5), and *large* (d=0.8).[49] A negative sign in the ES indicates a result that is closer to the baseline than the post-training value.[50]

Table 1. Average percentage difference between the external assessor's reported values for two practice voice samples in Praat

Dependent Variable	Voice Sample 1		Voice Sample 2		Average Percentage Difference
	VR01	VR04	VR02	VR03	
***MPT** (sec)*	20.15	20.08	24.60	23.79	1.85%
***Max F0** (Hz)*	995.10	994.88	983.14	977.21	2.90%
***Min F0** (Hz)*	147.25	146.82	153.17	162.34	2.76%
HNR	16.450	15.97	17.416	17.22	2.05%
***Mean SFF** (Hz)*	242.872	282.78	246.485	271.99	2.68%

RESULTS

Participant Profile and Raw Data

The three recruited female participants (i.e., P001, P002, P003) are almost the same age and duration of occupational voice use (Table 2). All work from home due to the global pandemic and the lockdown in the Philippines. Two participants had a minimum daily occupational voice use of 6 hours. The actual turn-out of weekly vocal training session frequency from weeks 2 to 4 are shown in Table 2. All the participants reportedly continued performing the lip trill exercise protocol in the succeeding week (Table 2). It was noteworthy that P003 performed the exercise daily during the maintenance phase (i.e., 7x-a-week). In contrast, P001 and P002 performed the exercise 5 and 6 times a week. None of the participants reported any vocal discomfort or voice issue for the duration of the study.

Table 2. Profile of the three recruited participants

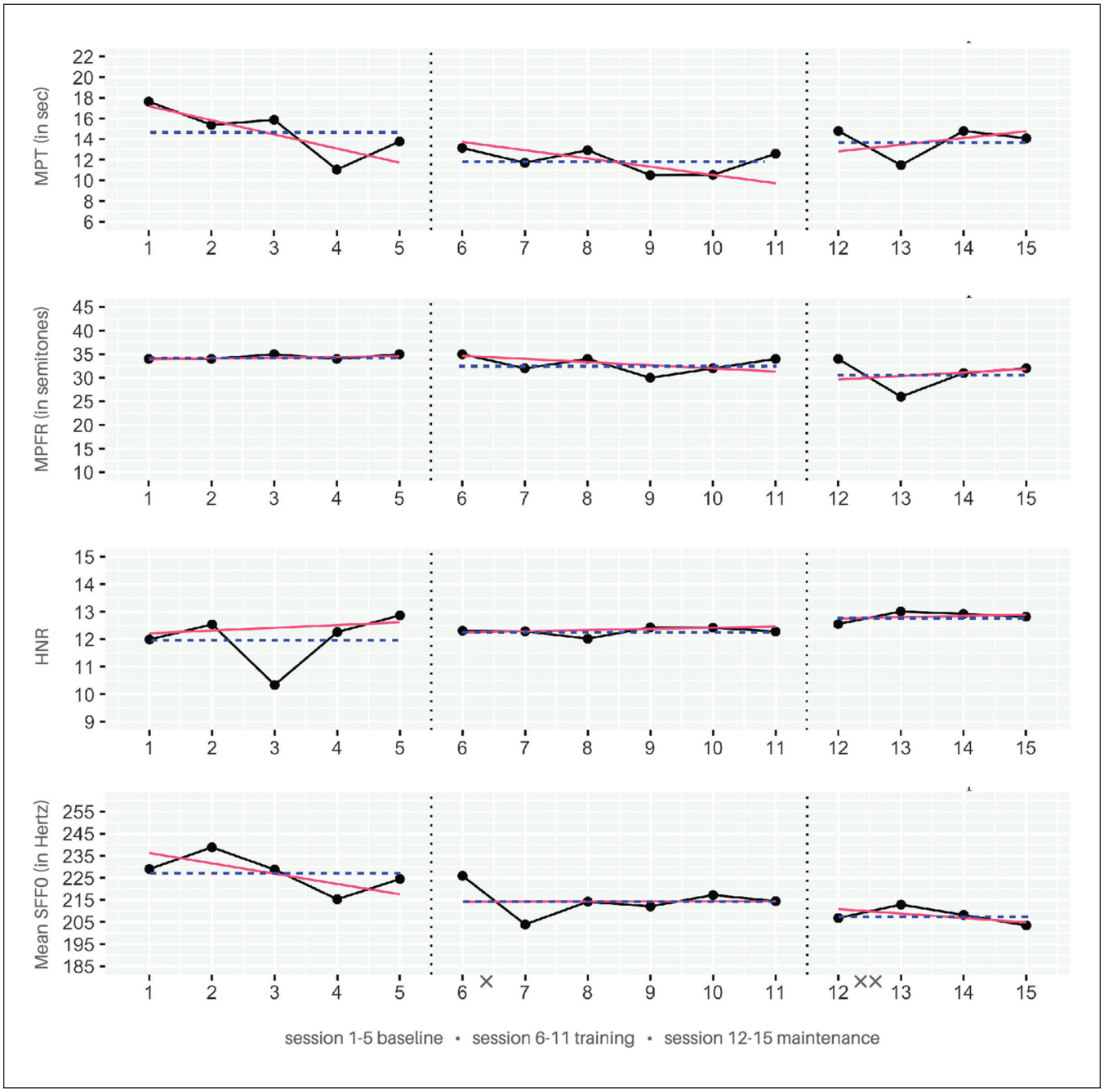
Participant	Age	Current Occupation	Duration of Occupational Voice Use (in Years)	Schedule	Number of training sessions	Frequency of training per week (Wk 2-Wk3-Wk4)
P001	33	Part-time SLP, Mother	10	7:20 am	6	1x-2x-3x
P002	34	College Teacher, Part-time SLP	11	7:00 am	5	0-3x-2x
P003	32	Radio broadcaster	10	7::40 am	7	2x-3x-2x

Within-Participant Visual Analysis Results

Participant 1 (P001)

P001's MPT decreased during the training phase. Its measurement almost reverted to a similar value as baseline (Figure 2). There was a lack of change in baseline and training phase trends. However, MPT was lower when P001 started vocal training sessions. A shift in the trend line was evident after the experimental condition as P001's MPT level increased during the maintenance phase. MPFR, on the other hand, became variable and slightly lowered as the study progressed. The increased variability suggests changing pitch control, while the slightly lowered MPFR suggests reduced pitch range.

In contrast, P001's HNR gradually improved in each phase, and the mean SFF decreased and varied less over



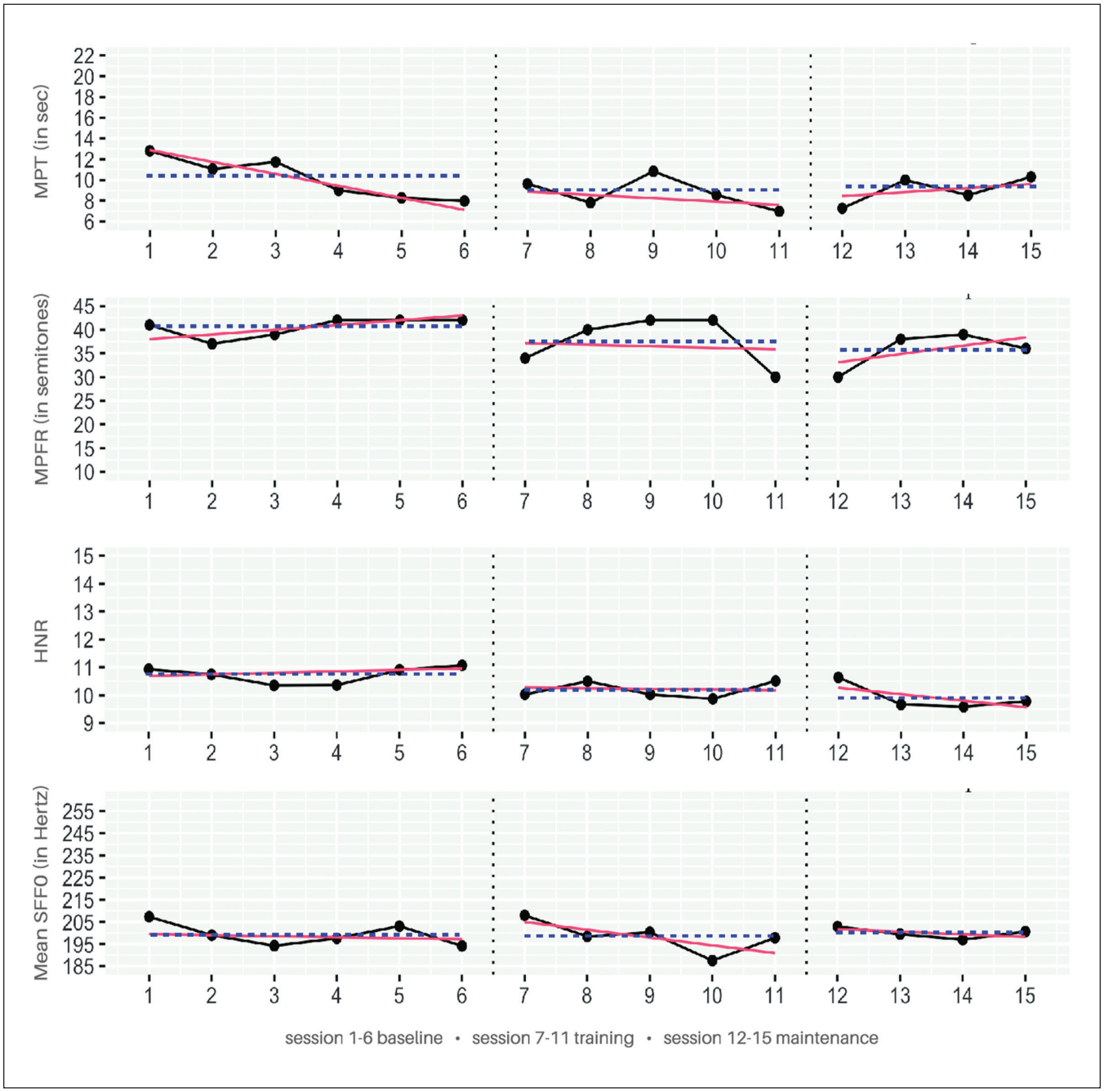
Note: Dotted vertical lines in the graph indicate the scope of each phase. The red line shows the trend line obtained through split middle technique. The blue broken line are the mean level lines.

Figure 2. P001's performance per session for each dependent variable.

time. This indicates an SFF with almost the same value every session despite being conducted on separate days. P001 expressed that the exercise improved her vocal freedom.

Participant 2 (P002)

P002's MPT trend and the level were similar to P001, although the difference was much less (Figure 3). P002's MPT trend lines took a downward direction for baseline and training phases but changed to an upward movement at the maintenance phase. On the other hand, P002's MPFR slightly declined as the study progressed. Trend analysis revealed an upward trend for the baseline and maintenance phase and a downward trend in the training phase. In terms of variability, MPFR made wider fluctuations when the training began, suggesting an effect on pitch control.



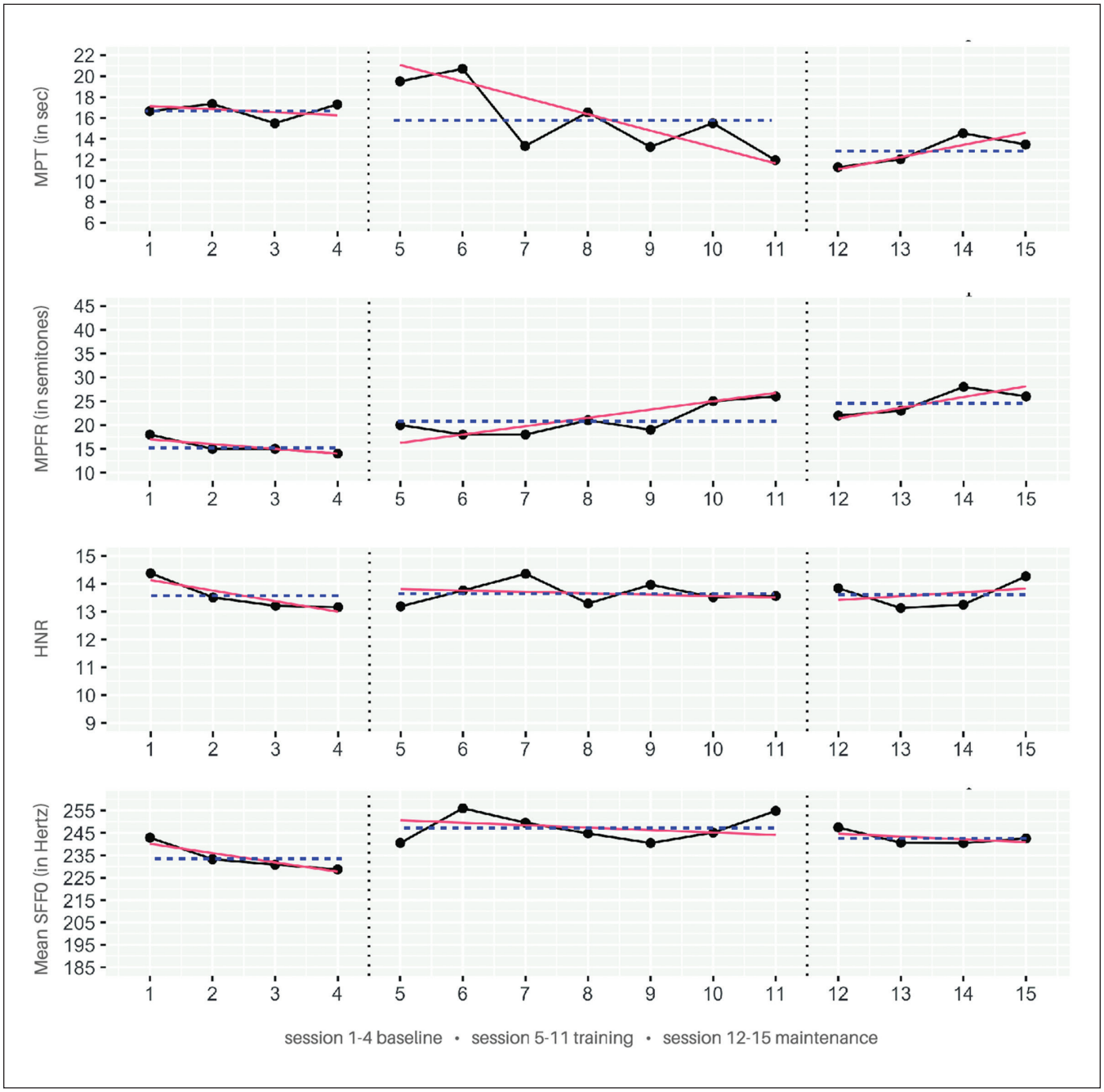
Note: Dotted vertical lines in the graph indicate the scope of each phase. The red line shows the trend line obtained through split middle technique. The blue broken line are the mean level lines.

Figure 3. P002's performance per session for each dependent variable.

On the other hand, P002's HNR declined slightly at every phase. HNR trends changed from slightly upward to slightly downward. Six out of 9 data points were plotted below the lower margin of P002's baseline performance, suggesting a decrease in HNR. P002's mean SFF remained relatively constant as her data points followed a flat line in all 3 phases, which indicates a lack of change. A decrease in SFF variability was also noted during the maintenance phase, similar to P001. P002 mentioned that she felt decreased tension in her neck when she started doing the exercise.

Participant 3 (P003)

P003 showed increased MPT during the first two training sessions and a decline thereafter (Figure 4). P003's baseline trend slightly tipped downward. Her training phase trend also showed a steep downward trend, but this was



Note: Dotted vertical lines in the graph indicate the scope of each phase. The red line shows the trend line obtained through split middle technique. The blue broken line are the mean level lines.

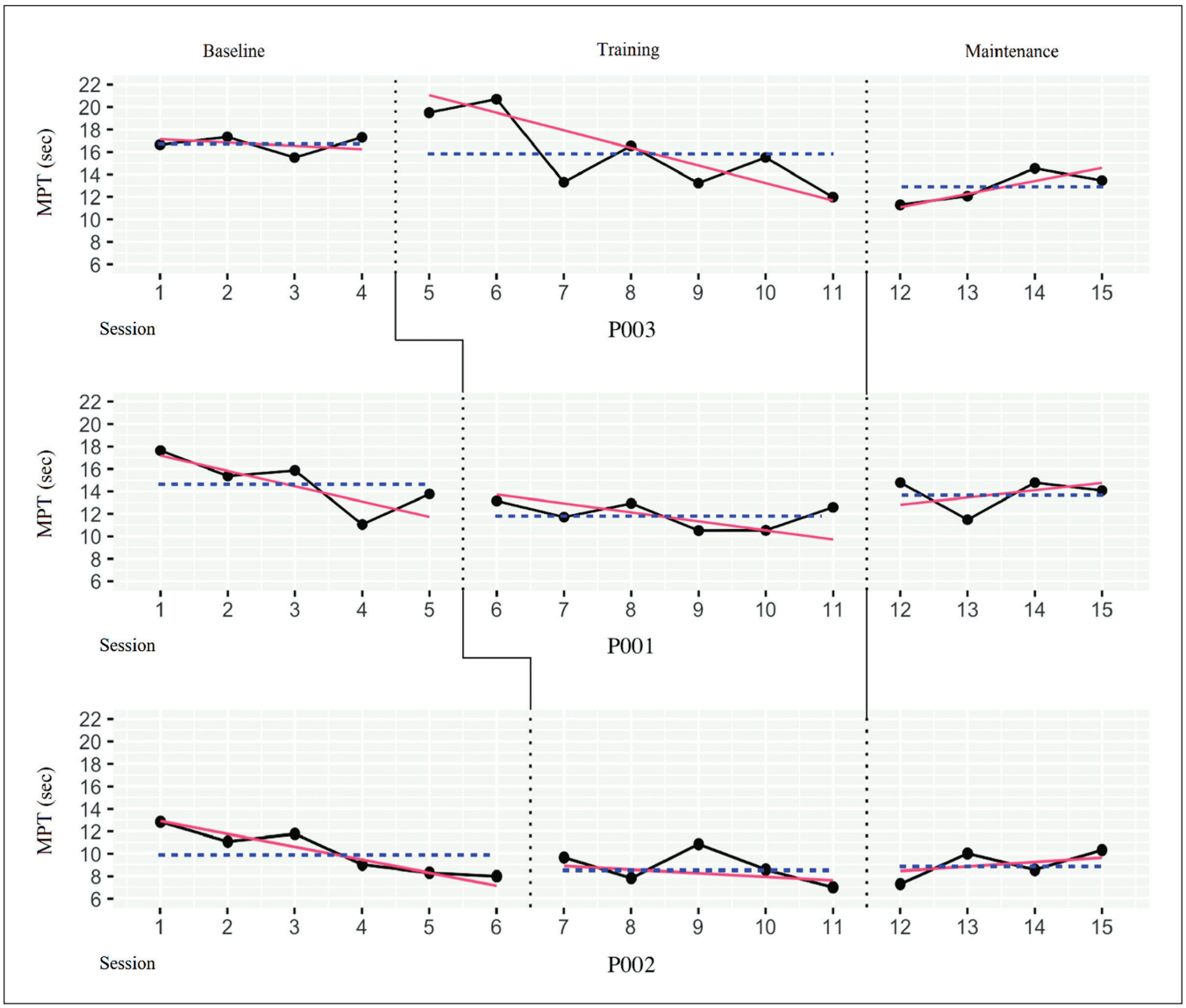
Figure 4. P003's performance per session for each dependent variable.

followed in the maintenance phase by an upward trend. In contrast, P003's MPFR increased from baseline to training. Her maximum F0 showed a gradual increase, while her minimum F0 decreased, thus widening her pitch range. All MPFR data points consistently followed an upward trend over time and resulted in wide variability in performance.

On the other hand, P003's HNR level lines were almost the same across phases. HNR variability remained relatively stable across phases. There was no evident change in HNR. P003's SFF increased during the training and maintenance phase. A decrease in variability was also apparent, similar to P001 and P002. P003 expressed that her voice feels conditioned after every lip trill exercise.

Between-Participant Visual Analysis Results

Maximum Phonation Time (MPT). All three participants exhibited a decrease in MPT (downward trend) during the training phase upon presenting the lip trill exercise protocol (Figure 5). This performance shifted upward by the maintenance phase across all three females. There was no consensus regarding performance variability, and only P003 demonstrated an immediate change upon starting the training. The rapid change was also interrupted and regressed to a downward trend as the training progressed. In contrast, P001 and P002 did not show any immediate or noticeable difference when training began. There is more than a 30% overlap between baseline and treatment phase measurements.



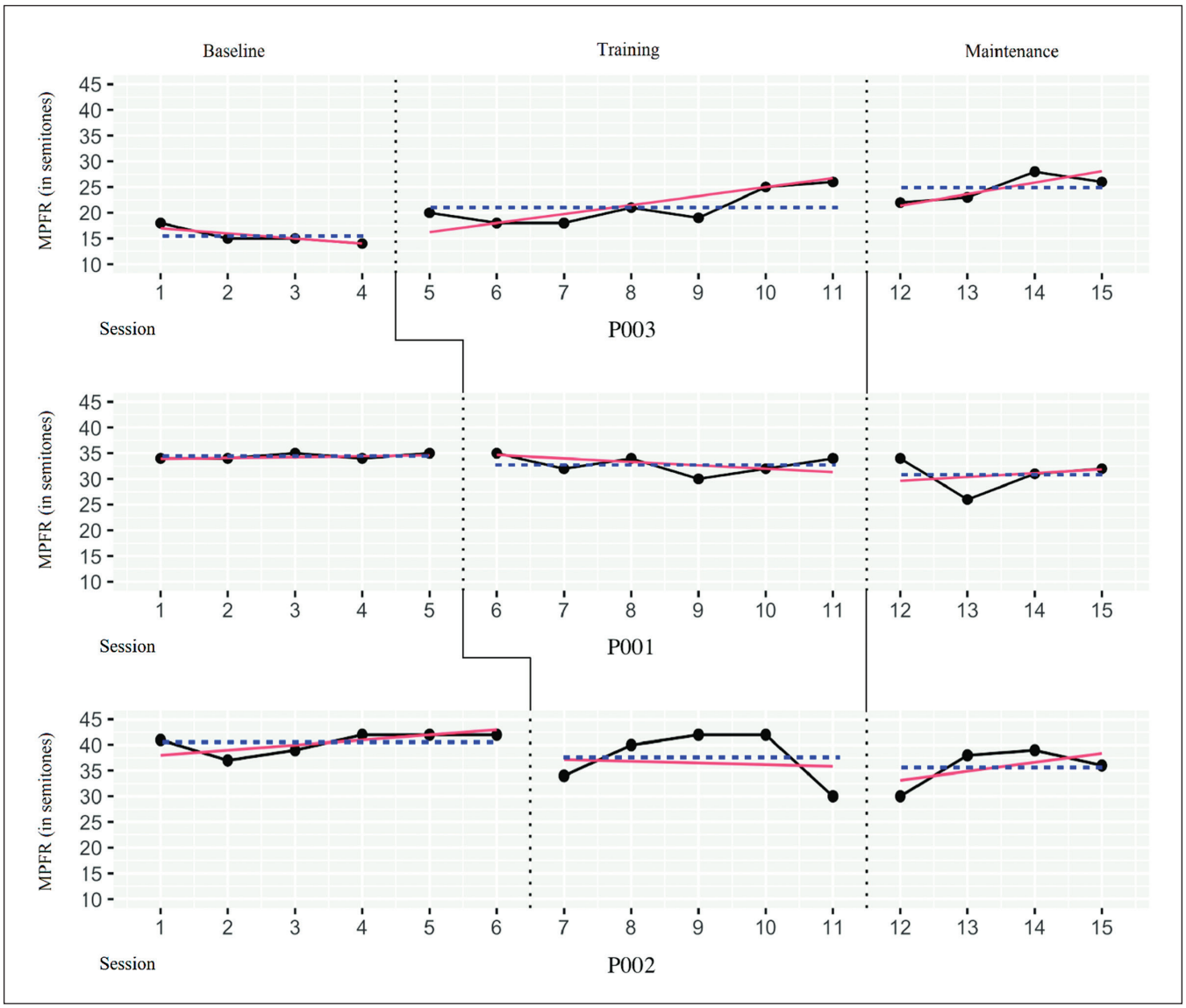
Note: The arrangement of the tiers followed the sequence by which they started their vocal training, i.e. P003-P001-P002. The black line shows the actual measurements. The trend lines are in red while the mean level lines are in blue.

Figure 5. Between-participant graph for maximum phonation time.

Maximum Phonation Frequency Range (MPFR). All 3 participants exhibited a wider variability in MPFR results since the training was introduced (Figure 6). There was no similarity in level and trend changes across the participants. All participants showed increased MPFR variability during the training phase, suggesting more pitches were produced when the lip trill protocol was introduced. The data remained variable by the maintenance phase. The overlap between baseline and training phase values was more than 30% for all participants. Only P003's graph provided evidence of an immediate effect.

Harmonics-to-Noise Ratio (HNR). There was no consistency in HNR level, trend, and variability across tiers (Figure 7). P003 showed increased stability of performance when the training was introduced. However, this was not evident in the other two participants. P002 and P003 demonstrated decreased and stable HNR values. This is different from P001, which, on the other hand, showed a slight increase in HNR. The degree of overlap was also more than 30%. There was also no evident immediate effect on any of the participants.

Mean Speaking Fundamental Frequency (mean SFF). All participants depicted a consistent decrease in mean SFF variability by the maintenance phase (Figure 8). In terms of level and trend, the results varied across the participants. While P003's mean SFF increased when training was introduced, P001's decreased. However, P002's mean SFF was relatively maintained. This suggests that the participants'



Note: The arrangement of the tiers followed the sequence by which they started their vocal training, i.e. P003-P001-P002. The black line shows the actual measurements. The trend lines are in red while the mean level lines are in blue.

Figure 6. Between-participant graph for maximum phonational frequency range.

mean SFF became relatively stable post-training. Overlap with baseline values was more than 30%. There is also no evidence of an immediate effect.

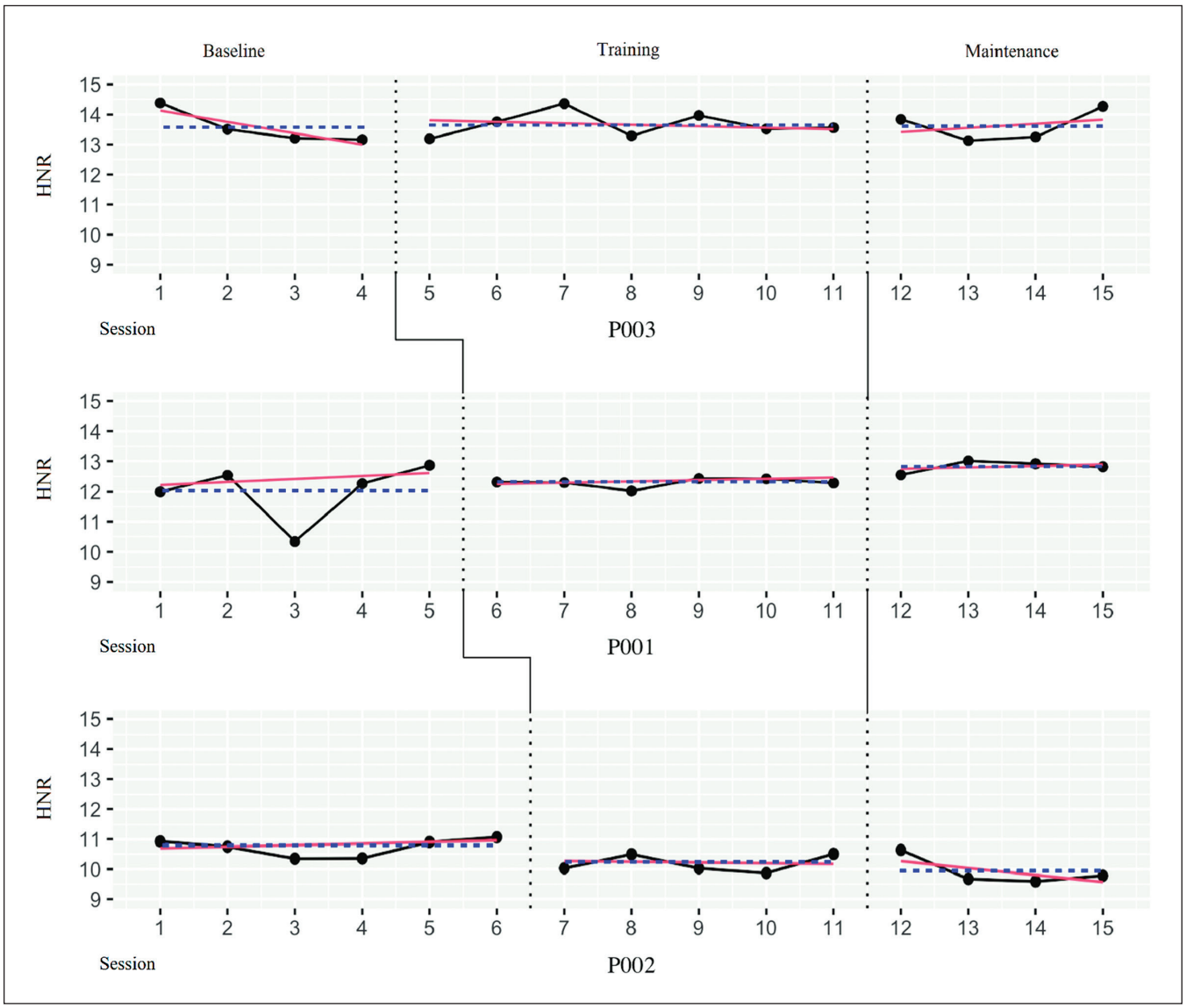
Results of Statistical Analysis

The data obtained were statistically analyzed using the Standardized Mean Difference measure of effect to obtain within-participant ES by comparing baseline and maintenance phase performance. Table 3 summarizes the results.

Findings showed a decrease in MPT on all participants. For MPFR, a large ES was seen in P003 and a decrease on the other two participants. For HNR, a small ES was seen in P003, a large ES was evident in P001, and a decrease on P002. Lastly, a large ES was clear on the SFF of P002 and P003, and a decrease on P001. As for the incidental findings: a) replicated increased SD during the training phase supports the visual findings of increased variability in MPFR when direct training commenced, while b) replicated decreased post-training SD supports the relatively stable post-training mSFF observed across the participants.

DISCUSSION

This study investigated the effects of the lip trill exercise on the MPT, MPFR, HNR, and SFF of 3 females with a perceptually normal voice. Results showed a lack of effect on MPT for all participants after the lip trill was introduced.



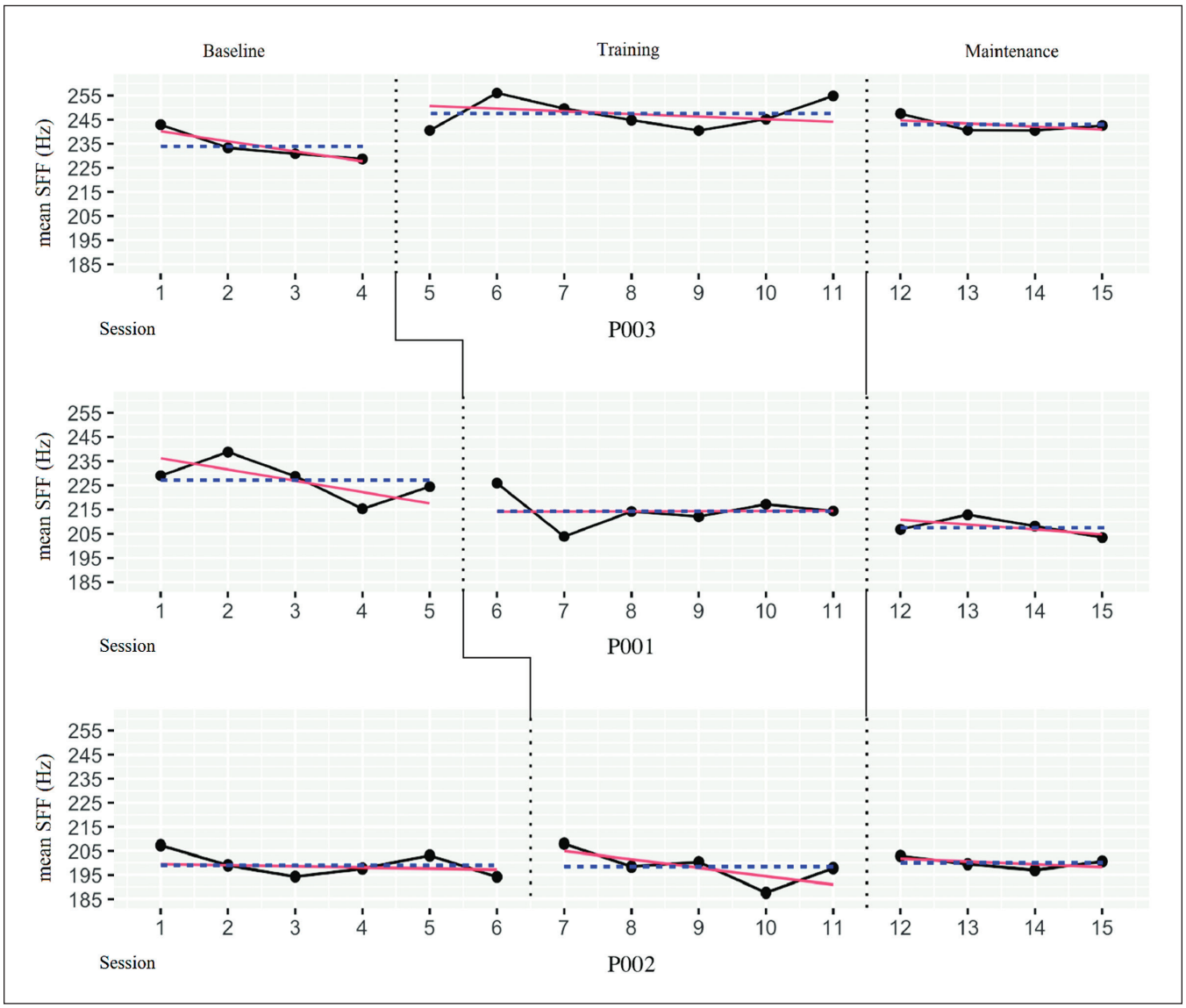
Note: The arrangement of the tiers followed the sequence by which they started their vocal training, i.e. P003-P001-P002. The black line shows the actual measurements. The trend lines are in red while the mean level lines are in blue.

Figure 7. Between-participant graph for harmonics-to-noise ratio.

On the other hand, MPFR, HNR, and SFF changes were seen in one or two participants but not across subjects. The other findings that showed replication include a) increased variability in MPFR and b) stabilized SFF following lip trill introduction. This also suggests that the 3-minute cumulative lip trill duration with less likelihood of vocal discomfort, as suggested by Menezes et al., is sufficient to cause vocal changes when done regularly.[30]

Effect on MPT

Our study results showed lower maintenance phase MPT compared to baseline. This opposed the findings of Lee et al. and supported that of Brockmann-Bauser et al.[15,29] Brockmann-Bauser et al. attributed the lack of significant change in MPT to the training duration being too short and the individual differences of the participants.[15] For our study, we found several reasons for this decrease. First, the consecutive implementation of training and assessment with short rest time in between could have affected the participants' performance. It must be noted that there were no lip trill exercises yet during the baseline phase, which means there was no vocal use before the assessment that obtained control data. Second, the supervised sessions and the maintenance phase length may not be enough to result in pronounced changes in MPT. Increased sessions could have given participants more time to adapt to the exercise mentally and physically, following the overload principle.[51] When the muscles are used more than usual, the bodily mechanisms involved are



Note: The arrangement of the tiers followed the sequence by which they started their vocal training, i.e. P003-P001-P002. The black line shows the actual measurements. The trend lines are in red while the mean level lines are in blue.

Figure 8. Between-participant graph for mean speaking fundamental frequency.

Table 3. Effect size comparing Baseline and Post-training/Maintenance Phase. Cohen's d was derived using the Standardized Mean Difference measure of effect for single-subject research[48]

	MPT Mean (SD)	MPFR Mean (SD)	HNR Mean (SD)	SFF Mean (SD)
P001				
Baseline	14.742 (2.483)	34.4 (0.548)	12 (0.984)	227.244 (8.501)
Training Phase	11.9033 (1.179)	32.833 (1.835)	12.292 (0.148)	214.598 (7.153)
Post-training	13.785 (1.573)	30.75 (3.403)	12.825 (0.199)	207.8125 (3.905)
d-index	-0.385	-6.664	0.839	-2.286
P002				
Baseline	10.14 (2.005)	40.5 (2.074)	10.728 (0.306)	199.197 (5.152)
Training Phase	8.756 (1.518)	37.6 (5.367)	10.188 (0.297)	198.392 (7.305)
Post-training	9.0225 (1.400)	35.75 (4.031)	9.92 (0.486)	199.95 (2.444)
d-index	-0.557	-2.291	-2.637	0.805
P003				
Baseline	16.6975 (0.859)	15.5 (1.732)	13.565 (0.565)	233.9375 (6.266)
Training Phase	15.8229 (3.312)	21 (3.266)	13.6643 (0.405)	247.3657 (6.342)
Post-training	12.835 (1.449)	24.75 (2.754)	13.6225 (0.532)	242.7925 (3.262)
d-index	-4.498	5.34	0.102	1.413

upregulated.[51] Thus, a more visible effect could have resulted if the participants had more time to adapt to the exercise.

On the other hand, the upward MPT trend during the maintenance phase suggests that a) the participants were more comfortable doing the lip trill exercise on their own, or b) the participants have started to adjust to the demands of the exercise. More than four weeks of regular use may be necessary if MPT can be increased by continued lip trill exercise.

Effect on MPFR

A replicated increase in variability of MPFR was noted across tiers, suggesting the presence of the effect.[46] However, data variability was still relatively high when the sessions ended. This made it harder to establish a functional relation than stable data.[47] There is also a possibility that effects have not yet settled by the time of the final session. An extended treatment phase could have provided a better picture of the lip trill effect. Thus, more than four weeks of lip trill exercise implementation may be needed to infer the effects fairly, at least for vocally untrained individuals.

On the other hand, although replication was not seen, the MPFR measurements of one participant showed an upward trend, a large ES, and a presence of an immediate effect. Her results support the findings of Lee et al. and Brockmann-Bauser et al. that MPFR is increased following lip trill.[15,29]

Effect on Harmonics-to-Noise Ratio

Changes in vocal harmonicity were seen in two out of three participants. This difference and the effect in the other participants suggest that HNR can be positively affected by lip trill exercises. However, even though HNR is an indicator of vocal function, studies on lip trill effects do not usually use it to quantify vocal change.[55] Given its importance in identifying pathological voices, including HNR changes in vocal monitoring is necessary. It is highly suggested that future large-scale studies on lip trill effects consider HNR as an outcome measure.

Effect on Mean Speaking Fundament Frequency

The lip trill had a significant effect on the SFF of two participants. This finding is similar to that of Brockmann-Bauser et al., who found increased SFF in their subjects following the lip trill exercise.[15] However, repeated measurements allowed us to see a narrowed variability in SFF measurements across all parti-cipants, specifically during the maintenance phase. This led us to conclude that, perhaps, a certain vocal state or condition is attained after each lip trill session, resulting in a decreased mean SFF variability for each participant. The finding is important as it supports the lip trill exercise protocol's potential as a vocal warm-up exercise. Sandage & Hoch explained the purpose of warm-up in reminding the body of optimal respiratory, laryngeal, and vocal tract configuration in singers.[51] Vocally untrained individuals may benefit similarly. This increased mean SFF stability was replicated in the other two participants and validated by a participant's feedback that the exercise conditions her voice in the morning. Perhaps this should be considered the most important finding from this study. This can only be seen with repeated measures and replicated change when single case experiments such as multiple-baseline studies across subjects are utilized.

Aside from the findings above, it should also be pointed out that the lowered SFF of one participant is of little account for two reasons. First, converting the values of the decreased SFF from 227 Hz at baseline to 207 Hz post-training to its musical scale counterparts, the resulting change is only one semitone lower (A3 to Ab3). However, it must be noted that within-speaker SFF, in this case, a one-semitone difference, can be influenced by emotional state.[52] While we did not ask for the participants' feelings and psychological states during the session, we argue that no one can have the same

emotional state all the time. Hence, we cannot rule out the possible influence of the emotional state on the subjects. Second, due to the highly individualized nature of the vocal pitch, it is difficult to determine if the change is toward the optimal pitch, i.e., the most efficient pitch at which a voice can be produced.[53,54] For this study, the optimal pitch was not determined. Thus, it is difficult to tell whether the changes in SFF were beneficial or otherwise.

Individual Differences and Vocal Training Gains

Positive vocal outcomes can be influenced by occupation, number of direct training sessions, and frequency of self-exercise. Radio broadcasters require optimal control of the voice and vocal characteristics.[56] Expert voice quality must attract listener attention, and pitch variation must be effective in phrasing and emphasizing.[57] On the other hand, speech-language pathologists' vocal effectiveness lies in their vocal stamina, power, and clarity.[58] The needs of the participants to become effective in their respective occupations lead to a choice of whether to achieve optimal voice, vocal attractiveness, vocal development, or vocal power. This can influence their motivation and commitment to the vocal training exercises. Motivation is vital in maximizing learning.[59] Notably, the radio broadcaster participant had the most vocal gains from the study. Aside from that, she received the greatest amount of instruction and had the most opportunity to learn from the PI.[59] As a result, she also had the most time to adjust to exercise demands. Her lip trill sessions ran for three weeks, in the following frequency: 2x-a-week (week 2 & 4) and 3x-a-week (week 3). Perhaps, 2- to 3- times per week vocal exercise frequency is ideal. After the last supervised session, the same participant consistently attended her sessions and performed the lip trill protocol daily (i.e., 7x-a-week). Since the therapeutic benefit is affected by the degree of adherence, it is highly likely that this participant's adherence also led to greater positive outcomes.[60] This supports the importance of motivation, training frequency, and adherence in creating positive vocal outcomes.

Participant Perceptions of Lip Trill Effects

While it is not an objective, we find the participant feedback on the lip trill exercises worth mentioning. In this study, all participants positively perceived exercise effects on vocal freedom, vocal stress, and vocal conditioning. Their mentioned vocal outcomes are not the ones measured by this study. While this can be a placebo effect, it still suggests that there may be other effects that future studies can investigate. We believe that different outcome measures are better suited to capture these effects. For instance, the measurement of the vocal economy as performed by Calvache et al. and the determination of closed glottal quotient as conducted by Gaskill & Erickson could provide objective evidence regarding vocal freedom and vocal stress.[16,18] Perhaps, a comprehensive voice assessment must also include such measures.

Future Research Directions

Researchers on prolonged lip trill effects should carefully consider our study's methodology, results, and limitations in designing their research protocols. A study utilizing a large sample size and standard equipment, and an acoustic environment that could enable between-subject comparisons is recommended to see the effects better. Instrumental assessment on laryngeal visualization, hearing screening, and aerodynamic capacity can also be performed during the screening and recruitment phase. Assessment sessions should be scheduled separately from the lip trill sessions to remove the influence of fatigue due to vocal training on the participants. The lip trill protocol performed by males who have been prescribed a longer duration of trill (5 minutes) can also be studied.[30] Research should also be conducted on the rate or frequency of voice disorder in those adhering to the lip trill exercise for direct voice care. This should include individuals with a high vocal load during in-person or face-to-face services. Lastly, a telepractice protocol or guidelines that enables reliable remote voice evaluation should also be created.

CONCLUSION

This study investigated the effect of a lip trill exercise protocol on three vocally untrained females with a perceptually normal voice. Although the lip trill effect on MPT is inconclusive, our investigation yielded the following: a) increase in variability for MPFR during the training phase and b) stabilized SFF during the maintenance phase. These findings suggest the lip trill effect on pitch control and vocal conditioning. The stabilized SFF after the exercise validates the lip trill exercise's applicability in the vocal warm-up. Given the results, the 3-minute cumulative lip trill duration influenced vocal parameters with regular exercise.[30] Vocal outcomes may vary depending on motivation, exercise frequency, and adherence. Future related research that examines prolonged lip trill effects should consider this study's methodology, results, and limitations in designing their research protocol.

Acknowledgments

We thank Dr. Meike Brockmann-Bauser for allowing us to adapt and modify the treatment protocol of her study. We also acknowledge the College of Allied Medical Professions, Prof. Michael Valdez, Prof. Fernando Alejandro Ligot, Dr. Ivan Paul Bondoc, Prof. Kathy Brander, and Prof. Ralph Kevin Genoguin for their support, insights, and expertise.

Statement of Authorship

Both authors contributed in the conceptualization of work, acquisition and analysis of data, drafting and revising and approved the final version submitted.

Author Disclosure

Both authors declared no conflicts of interest.

Funding Source

This study has no funding support.

REFERENCES

1. Cantor Cutiva LC, Vogel I, Burdorf A. Voice Disorders in Teachers and Their Associations with Work-related Factors: A Systematic Review. J Commun Disord. 2013 Mar-Apr;46(2):143-55. doi:10.1016/j.jcomdis.2013.01.001.
2. John R, Poduval JD. Voice Training for Professional Voice Users. J Sci Res Rep. 2015;65-68.
3. Morawska J, Niebudek-Bogusz E. Risk Factors and Prevalence of Voice Disorders in Different Occupational Groups – A Review of Literature. Otorynolaryngologia. 2017;16(3):94-102.
4. Vilkman E. Occupational Risk Factors and Voice Disorders. Logoped Phoniatr Vocol. 1996;21(3-4):137-41. doi:10.3109/14015439609098881
5. Vilkman E. Voice problems at work: A Challenge for Occupational Safety and Health Arrangement. Folia Phoniatr Logop. 2000 Jan-Jun;52(1-3):120-5. doi:10.1159/000021519.
6. Duffy OM, Hazlett DE. The Impact of Preventive Voice Care Programs for Training Teachers: A Longitudinal Study. J Voice. 2004 Mar;18(1):63-70. doi:10.1016/S0892-1997(03)00088-2.
7. López JM, Catena A, Montes A, Castillo ME. Effectiveness of a Short Voice Training Program for Teachers: A Preliminary Study. J Voice. 2017 Nov;31(6):697-706. doi:10.1016/j.jvoice.2017.01.017.
8. Pasa G, Oates J, Dacakis G. The Relative Effectiveness of Vocal Hygiene Training and Vocal Function Exercises in Preventing Voice Disorders in Primary School Teachers. Logoped Phoniatr Vocol. 2007;32(3):128-40. doi:10.1080/14015430701207774.
9. Timmermans B, Vanderwegen J, De Bodt MS. Outcome of Vocal Hygiene in Singers. Curr Opin Otolaryngol Head Neck Surg. 2005 Jun;13(3):138-42. doi:10.1097/01.moo.0000163351.18015.b6.
10. Santos AC, Borrego MC, Behlau M. Effect of Direct and Indirect Voice Training in Speech-Language Pathology and Audiology Students. Codas. 2015 Jul-Aug;27(4):384-91. English, Portuguese. doi:10.1590/2317-1782/20152014232.
11. Broaddus-Lawrence PL, Treole K, McCabe RB, Allen RL, Toppin L. The Effects of Preventive Vocal Hygiene Education on the Vocal Hygiene Habits and Perceptual Vocal Characteristics of Training Singers. J Voice. 2000 Mar;14(1):58-71. doi:10.1016/s0892-1997(00)80095-8.
12. Pizolato RA, Beltrati Cornacchioni Rehder MI, dos Santos Dias CT, de Castro Meneghim M, Bovi Ambrosano GM, Mialhe FL, et al. Evaluation of the Effectiveness of a Voice Training Program for Teachers. J Voice. 2013 Sep;27(5):603-10. doi:10.1016/j.jvoice.2013.04.013.
13. Fletcher HM, Drinnan MJ, Carding PN. Voice Care Knowledge among Clinicians and People with Healthy Voices or Dysphonia. J Voice. 2007 Jan;21(1):80-91. doi:10.1016/j.jvoice.2005.09.002.
14. Przysiezny PE, Przysiezny LT. Work-related Voice Disorder. Braz J Otorhinolaryngol. 2015 Mar-Apr;81(2):202-11. doi:10.1016/j.bjorl.2014.03.003.
15. Brockmann-Bauser M, Balandat B, Bohlender JE. Immediate Lip Trill Effects on the Standard Diagnostic Measures Voice Range Profile, Jitter, Maximum Phonation Time, and Dysphonia Severity Index. J Voice. 2020 Nov;34(6):874-83. doi:10.1016/j.jvoice.2019.04.011.
16. Calvache C, Guzman M, Bobadilla M, Bortnem C. Variation on Vocal Economy After Different Semioccluded Vocal Tract Exercises in Subjects With Normal Voice and Dysphonia. J Voice. 2020 Jul;34(4):582-589. doi:10.1016/j.jvoice.2019.01.007.
17. Araujo CMT, Gomes ADC, Vasconcelos D. Voiced Lip Trill and Tongue Trill Technique: Literature Review. São Paulo. 2016 September;28(3):581-93.
18. Gaskill CS, Erickson ML. The Effect of a Voiced Lip Trill on Estimated Glottal Closed Quotient. J Voice. 2008 Nov;22(6):634-43. doi:10.1016/j.jvoice.2007.03.012.
19. Kaneko M, Sugiyama Y, Mukudai S, Hirano S. Effect of Voice Therapy Using Semioccluded Vocal Tract Exercises in Singers and Nonsingers With Dysphonia. J Voice. 2020 Nov;34(6):963.e1-963.e9. doi:10.1016/j.jvoice.2019.06.014.
20. Meerschman I, Van Lierde K, Ketels J, Coppieters C, Claeys S, D'haeseleer E. Effect of Three Semi-occluded Vocal Tract Therapy Programmes on the Phonation of Patients with Dysphonia: Lip Trill, Water-resistance Therapy and Straw Phonation. Int J Lang Commun Disord. 2019 Jan;54(1):50-61. doi:10.1111/1460-6984.12431.
21. Nam IC, Kim SY, Joo YH, Park YH, Shim MR, Hwang YS, et al. Effects of Voice Therapy Using the Lip Trill Technique in Patients With Glottal Gap. J Voice. 2019 Nov;33(6):949.e11-949.e19. doi:10.1016/j.jvoice.2018.07.013.
22. de Vasconcelos D, Gomes AO, de Araújo CM. Treatment for Vocal Polyps: Lips and Tongue Trill. J Voice. 2017 Mar;31(2):252.e27-252.e36. doi:10.1016/j.jvoice.2016.07.003.
23. Nix J, Simpson CB. Semi-occluded Vocal Tract Postures and Their Application in the Singing Voice Studio. J Acoust Soc Am. 2007;121:3087.
24. Titze IR. Voice Training and Therapy with a Semi-occluded Vocal Tract: Rationale and Scientific Underpinnings. J Speech Lang Hear Res. 2006 Apr;49(2):448-59. doi:10.1044/1092-4388(2006/035).
25. Story BH, Laukkanen AM, Titze IR. Acoustic Impedance of an Artificially Lengthened and Constricted Vocal Tract. J Voice. 2000 Dec;14(4):455-69. doi:10.1016/s0892-1997(00)80003-x.
26. Bele IV. Artificially Lengthened and Constricted Vocal Tract in Vocal Training Methods. Logoped Phoniatr Vocol. 2005;30(1):34-40. doi:10.1080/14015430510006677.
27. Titze I, Riede T, Popolo P. Nonlinear Source-filter Coupling in Phonation: Vocal Exercises. J Acoust Soc Am. 2008 Apr;123(4):1902-15. doi:10.1121/1.2832339.
28. Andrade PA, Wood G, Ratcliffe P, Epstein R, Pijper A, Svec JG. Electroglottographic Study of Seven Semi-occluded Exercises: LaxVox, Straw, Lip-trill, Tongue-trill, Humming, Hand-over-mouth, and Tongue-trill Combined with Hand-over-mouth. J Voice. 2014 Sep;28(5):589-95. doi:10.1016/j.jvoice.2013.11.004.
29. Lee SJ, Choi HS, Lim J, Lee KY. The Effect of the Modified Voiced Lip Trill (MVOLT) Training on Vocal Changes of Musical Theater Students. Phonetics Speech Sci. 2018;10(4):135-46. doi:10.13064/KSSS.2018.10.4.135
30. Menezes MH, de Campos Duprat A, Costa HO. Vocal and Laryngeal Effects of Voiced Tongue Vibration Technique According to Performance Time. J Voice. 2005 Mar;19(1):61-70. doi:10.1016/j.jvoice.2003.11.002.
31. Dargin TC. The Impact of Semi-occluded Vocal Tract Exercises on Vocal Function in Singers: Straw Phonation vs. Lip Trill. [senior research project]. Lawrence (KS): University of Kansas; 2008.
32. Smith JD. Single-case Experimental Designs: A Systematic Review of Published Research and Current Standards. Psychol Methods. 2012 Dec;17(4):510-50. doi:10.1037/a0029312.
33. Krasny-Pacini A, Evans J. Single-case Experimental Designs to Assess Intervention Effectiveness in Rehabilitation: A Practical Guide. Ann Phys Rehabil Med. 2018 May;61(3):164-79. doi:10.1016/j.rehab.2017.12.002.
34. Hawkins NG, Sanson-Fisher RW, Shakeshaft A, D'Este C, Green LW. The Multiple Baseline Design for Evaluating Population-based Research. Am J Prev Med. 2007 Aug;33(2):162-8. doi:10.1016/j.amepre.2007.03.020.
35. Gelinas L, Pierce R, Winkler S, Cohen IG, Lynch HF, Bierer BE. Using Social Media as a Research Recruitment Tool: Ethical Issues and Recommendations. Am J Bioeth. 2017 Mar;17(3):3-14. doi:10.1080/15265161.2016.1276644.
36. Whitaker C, Stevelink S, Fear N. The Use of Facebook in Recruiting Participants for Health Research Purposes: A Systematic Review. J Med Internet Res. 2017 Aug 28;19(8):e290. doi:10.2196/jmir.7071.

37. Consensus Auditory-Perceptual Evaluation of the Voice [Internet]. Rockville (MD): American Speech-Language-Hearing Association; c2009 [cited 2021 June 16]. Available from https://www.asha.org/siteassets/uploadedfiles/asha/sig/03/cape-v-procedures-and-form.pdf
38. Lobo MA, Moeyaert M, Baraldi Cunha A, Babik I. Single-Case Design, Analysis, and Quality Assessment for Intervention Research. J Neurol Phys Ther. 2017 Jul;41(3):187-97. doi:10.1097/NPT.0000000000000187.
39. Portney LG, Watkins MP. Foundations of Clinical Research: Applications to Practice. 3rd ed. Philadelphia (PA): FA Davis Company; 2015.
40. Colton RH, Casper JK, Leonard R. Understanding Voice Problems: A Physiological Perspective for Diagnosis and Treatment. 4th ed. Philadelphia (PA): Wolters Kluwer Health/Lippincott Williams & Wilkins; 2011.
41. Physics of Music – Notes: Tuning [Internet]. Houghton: Michigan Technological University, Department of Physics; [cited 2021 June 16]. Available from https://pages.mtu.edu/~suits/notefreqs.html.
42. Britto AI, Doyle PC. A Comparison of Habitual and Derived Optimal Voice Fundamental Frequency Values in Normal Young Adult Speakers. J Speech Hear Disord. 1990 Aug;55(3):476-84. doi:10.1044/jshd.5503.476.
43. Hollien H, Dew D, Philips P. Phonational Frequency Ranges of Adults. J Speech Hear Res. 1971 Dec;14(4):755-60. doi:10.1044/jshr.1404.755.
44. Teixeira JP, Oliveira C, Lopes C. Vocal Acoustic Analysis - Jitter, Shimmer and HNR Parameters. Procedia Technology. 2013;9:1112. doi:10.1016/j.protcy.2014.10.138
45. Lane JD, Gast DL. Visual Analysis in Single Case Experimental Design Studies: Brief Review and Guidelines. Neuropsychol Rehabil. 2014;24(3-4):445-63. doi: 10.1080/09602011.2013.815636.
46. Wolfe K, Barton EE, Meadan H. Systematic Protocols for the Visual Analysis of Single-Case Research Data. Behav Anal Pract. 2019 Jan 28;12(2):491-502. doi:10.1007/s40617-019-00336-7.
47. Ledford JR, Zimmerman KN, Schwartz I, Odom S. Guide of the Use of Single Case Research Evidence [Internet]. Council for Exceptional Children: Division for Research; 2018 [cited 2021 May 12]. Available from https://higherlogicdownload.s3.amazonaws.com/SPED/b7acd4b4-bc4d-4c1f-a7d4-efab3d52da44/UploadedImages/Evidence%20Based%20Practice/CEC-DR_SCD_Guide.pdf.
48. Beeson PM, Robey RR. Evaluating Single-subject Treatment Research: Lessons Learned from the Aphasia Literature. Neuropsychol Rev. 2006 Dec;16(4):161-9. doi:10.1007/s11065-006-9013-7.
49. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers; 1988.
50. The Starpath Project. The University of Auckland. Effect sizes [Internet]. [New Zealand]: The University of Auckland. [cited in 2021 May 21]. Available from https://cdn.auckland.ac.nz/assets/education/about/research/starpath/documents/data/working-with-data-resources/skills/Effect%20Size.docx
51. Sandage MJ, Hoch M. Exercise Physiology: Perspective for Vocal Training. J Sing. 2018 Mar/Apr;74(4): 419-25.
52. Traunmüller H, Eriksson A. The Frequency Range of the Voice Fundamental in the Speech of Male and Female Adults [Internet]. [place unknown: publisher unknown]. 1993 [cited 2021 May 23]. Available from http://www2.ling.su.se/staff/hartmut/f0_m&f.pdf.
53. Titze IR. Physiologic and Acoustic Differences between Male and Female Voices. J Acoust Soc Am. 1989 Apr;85(4):1699-707. doi:10.1121/1.397959.
54. Huss PJ. Vocal Pitch Range and Habitual Pitch Level: The Study of Normal College Age Speakers [senior research project]. Kalamazoo (MI): Western Michigan University; 1983.
55. Ferrand CT. Harmonics-to-noise Ratio: An Index of Vocal Aging. J Voice. 2002 Dec;16(4):480-7. doi:10.1016/s0892-1997(02)00123-6.
56. Warhurst S, McCabe P, Madill C. What Makes a Good Voice for Radio: Perceptions of Radio Employers and Educators. J Voice. 2013 Nov;27(2):217-24. doi:10.1016/j.jvoice.2012.08.010
57. Neil E, Worrall L, Day A, Hickson L. Voice and Speech Characteristics and Vocal Hygiene in Novice and Professional Broadcast Journalists. Adv Speech Lang Pathol. 2003;5(1):1-14. doi:10.1080/14417040510001669001.
58. Couch S, Zieba D, Van der Linde J, Van der Merwe A. Vocal Effectiveness of Speech-Language Pathology Students: Before and After Voice Use during Service Delivery. S Afr J Commun Disord. 2015 Mar 26;62(1):E1-7. doi:10.4102/sajcd.v62i1.95.
59. McIlwaine A, Madill C, McCabe P. Voice Therapy Prepractice and the Principles of Motor Learning. Acquir Knowl Speech Lang Hear. 2010;12(1):29–32.
60. Verdolini-Marston K, Burke MK, Lessac A, Glaze L, Caldwell E. Preliminary Study of Two Methods of Treatment for Laryngeal Nodules. J Voice. 1995 Mar;9(1):74-85. doi:10.1016/s0892-1997(05)80225-5.