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Relationships among audiological measurements, tinnitus measurements and self-reported hearing handicap in subjects with occupational hearing loss

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RELATIONSHIPS AMONG AUDIOLOGICAL MEASUREMENTS, TINNITUS MEASUREMENTS AND SELF REPORTED HEARING HANDICAP IN SUBJECTS WITH OCCUPATIONAL HEARING LOSS

by

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ABSTRACT

In twenty-nine male claimants for workman's compensation, relationships were explored among audiological measures, the severity of tinnitus, and self-reported hearing handicap (the Hearing Handicap Scale). Correlation and regression analysis were used to evaluate the data. Most correlations were low. The highest correlation was between Tinnitus - sensation level and perceived hearing handicap ($r = 0.51$). Better ear pure-tone average did not have a high correlation to perceived hearing handicap ($r = 0.17$). This was an unexpected finding. Regression analysis indicated that tinnitus - sensational level was a more important factor than Binaural Impairment (%) in predicting hearing handicap. A conclusion that may be drawn from the present study is that workman's compensation should be based more on tinnitus annoyance than hearing loss. Because this was such an unexpected finding, we should confirm this result in a more general population.

INTRODUCTION

Types of Tinnitus

Subjective tinnitus is the perception of internal noise in the ear or in the head without any external acoustic stimuli (Axelsson & Ringdahl, 1989; Penner, 1983). Tinnitus prevalence varies from study to study depending on how tinnitus is defined. In the U.S.A., a general population survey indicated that 32% of the population had some form of tinnitus. In both the United States and the United Kingdom, 2% of tinnitus sufferers report severe tinnitus (National Center for Health Statistics, 1967, 1980; Institute of Hearing Research, 1981).

Stouffer & Tyler (1990) found that the most common descriptors for the quality of tinnitus were “ringing”, “buzzing”, "cricket" and “hissing”. Tinnitus of a pure tone character was most common, followed by narrow-band noise and a combination of both. A broad-band noise type of tinnitus was the least common finding (Alberti, 1987; Axelsson & Sandh, 1985).

Incidence of Tinnitus

Tinnitus is common in noise-induced hearing loss. Since males tend to work in noisy environments more than females, it would be expected that males would report tinnitus more frequently than females (Axelsson & Ringdahl, 1989). Alberti (1987) and Axelsson & Sandh (1985) reported that the incidence of tinnitus appears to be higher for those who are exposed to impulsive noise or other acoustic trauma than for those exposed to continuous noise. Chung, Gannon & Mason (1984) stated that hearing threshold is the most important factor that affects the prevalence of tinnitus for noise-induced hearing loss subjects. There is a distinct increase in the prevalence of tinnitus as hearing loss increases.

Consequences of Tinnitus

Many tinnitus sufferers report that tinnitus interferes with speech perception; they are not able to distinguish words in a noisy background, and everyday sounds are not loud enough for them. However, many tinnitus sufferers also have a hearing loss. It is impossible to differentiate whether it is the tinnitus that interferes with speech perception or whether it is the hearing loss (Axelsson & Ringdahl, 1989; Stouffer & Tyler, 1990; Tyler & Baker, 1983).

Hearing and sleep difficulties are the most prominent complaints from tinnitus sufferers. In addition, tinnitus patients complain that tinnitus interferes their with daily lives, affecting communication, health and emotional well-being (Hallberg, Johnsson & Axelsson, 1993; Sanchez & Stephens, 1997; Tyler & Baker, 1983).

Factors Influencing the Measurement of Tinnitus

Masking tinnitus can be different than masking an externally generated sound. When people with normal hearing listen to a pure-tone signal, the masker energy outside a restricted frequency bandwidth is relatively ineffective in masking the pure-tone signal (Fletcher, 1940). However, this is not the case for some people whose tinnitus sounds like a pure tone or narrow-band noise. Feldmann (1971) and Shailer, Tyler & Coles (1981) reported that a pure tone at a frequency far removed from that of the tinnitus can be effective in masking the tinnitus. In addition, Feldmann (1971) reported that in many subjects with tinnitus, the noise level required to mask the tinnitus was independent of center frequency, regardless of the pitch of the tinnitus. In the usual masking situation, a pure tone can easily be masked by a broad band noise, but a broad band noise can hardly be masked by a pure tone (Feldmann, 1971). In tinnitus situations, however, it was found that an external tone can easily mask an internal noise-type tinnitus (Mitchell, 1983; Vernon, Johnson, Schleuning & Mitchell, 1980).

In the usual tone-tone masking situation, it is easy to produce beats when a subject is presented with two tones differing in frequency by only a few cycles per second (e.g., 1000 and 1003Hz) at the same time (Gelfand, 1998). The production of beats between an external tone and the tinnitus is very rare, even when the tinnitus has tonal quality (Vernon et al., 1980). Also, neither the pitch nor the loudness of the tinnitus sensation correlates with its maskability (Mitchell, 1983; Vernon et al., 1980).

Feldmann (1971) indicated that tinnitus masking curves were found to differ significantly from conventional masking curves. The levels that are necessary for the masking of tinnitus in 200 patients can be classified into five types:
(a) Convergence, when the threshold curve and the masking curve converge on the audiometric curve at the high frequencies. (b) Divergence, when threshold and masking curves diverge from low to high frequencies. (c) Congruence, when the audiometric curve and the masking curve are congruent within 10dB. (d) Distance, when a higher sensation level is required to achieve masking, and (e) Resistance, when no masking was obtained by any kind of stimulus.

Most of the patients suffering from tinnitus are able to identify the pitch of their tinnitus consistently (Cahani, Paul & Shahar, 1983). The pitch of tinnitus is usually concentrated in the high frequency range in patients with noise-induced hearing loss (Cahani et al., 1983; Feldmann, 1971; Man & Naggan, 1981). However, correlation between the tinnitus pitch and the audiometric frequency at which the hearing loss was the most severe was not found (Man & Naggan, 1981; Stouffer & Tyler, 1990).

In noise-induced hearing loss, there is a clear correlation between the level of tinnitus and the hearing loss level at the frequency at which the hearing loss is the most severe (Axelsson & Sandh, 1985; Man & Naggan, 1981). Many patients estimate their tinnitus at a level 5 to 10dB above their hearing threshold (Man & Naggan, 1981; Reed, 1960). However, a discrepancy often remains between the description of the patient's tinnitus-related problems and the estimated level of the tinnitus. In cases of sensorineural hearing loss, recruitment might contribute to this discrepancy. Psychological problems such as headache, depression and sleep disturbances could also influence the perception of the tinnitus level (Lingberg, Lyttkens, Melin & Scott, 1984).

Purpose of Study

The aims of the independent study are to examine:

1. The correlation between self-reports on the Hearing Handicap Scale and audiological measures.
2. The relationship between severity of tinnitus and the degree of hearing handicap.

Methods

Subjects

The subjects were 29 males; the mean age was 51 (SD = 9.78) with a range from 24-66 years. The subjects were a group of CID patients who had submitted claims for workman's compensation between February 1996 and February 2000. The subjects claimed that their hearing impairment was due to years of noise exposure in their working environment.

Procedures

All subjects reported tinnitus at the time of the audiological examination. They were examined with a comprehensive audiological evaluation that included air conduction, bone conduction, speech reception thresholds (CID Auditory Test W-1), and speech discrimination (CID Auditory Test W-22). The pitch and loudness of the tinnitus was also measured. At the end of the testing, the Tinnitus Questionnaire (Shulman, 1991) and the Hearing Handicap Scale (High, Fairbanks, and Glorig, 1964) were completed by each subject to estimate the severity of their symptoms.

Tinnitus Questionnaires (Tinnitus - Score)

The questions on the Tinnitus Questionnaire were designed to determine how much of a problem the tinnitus imposed on a patient (Appendix A).

The Hearing Handicap Scale (HHS)

The items on the Hearing Handicap Scale are focused primarily on everyday listening experiences. The language of the items was carefully chosen to maintain a low level of reading difficulty so that it could be used to evaluate subjects within a wide age range. In addition, a uniform question style was used to keep the flow of thought constant during evaluation (Appendix B).

Pitch Matching

Tinnitus pitch was established in each case by using paired comparisons. Two tones differing in frequency were presented at the same Sensation Level, one after the other, contralaterally to the affected ear. Each subject was instructed to choose the tone that was more like the pitch of the tinnitus. For example, if the subject thought the tinnitus to be closest to a high-frequency pure tone, the first pair might have been a 1kHz followed by a 2kHz pure tone. If the second was judged to be the closest, then a 2kHz tone followed by 4kHz tone was presented and so on, until the closest match was obtained.

Loudness Matching

The loudness matching procedure was the same as pitch matching. Two stimuli were presented in pairs contralaterally to the affected ear. A frequency where the hearing threshold was normal was chosen as the test frequency. For example, the two stimuli were presented at 10dB and 20dB above the most normal pure-tone threshold. Each subject was asked to report which level was closer to the loudness of his/her tinnitus. The choice of the subject was then paired with a different intensity. The procedure was repeated until a single sensation level was consistently chosen.

RESULTS

Correlations Between Self-Reports on the Hearing Handicap Scale and Audiological Measures

One of the objectives of this study was to determine the relationships between the standard audiological tests and a measure of hearing handicap. These relationships were investigated using correlation coefficients. Table 1 shows the correlations between the Hearing Handicap Scale to audiological measures and tinnitus measurement in order of significance from most significant to least. Table 2 shows the mean and standard deviation of the variables.

Table. 1 Summary of Correlations relating the Hearing Handicap Scale to Audiometric Measures and Tinnitus Measurement.

Audiometric Measure	Correlation	Degree of Correlation
Tinnitus - Sensation Level (SL)	0.51	Moderate
Speech Discrimination Score - R	-0.34	Mild
Speech Discrimination Score - L	-0.26	Mild
PTA - L (0.5, 1, 2kHz)	0.23	Mild
Tinnitus Questionnaire - Tinnitus Score	0.23	Mild
PTA - Better	0.17	Not Significant
Binaural Impairment (%)	0.13	Not Significant
PTA - Worst	0.12	Not Significant
PTA - R (0.5, 1, 2kHz)	0.06	Not Significant
Speech Reception Threshold - R	0.03	Not Significant
Speech Reception Threshold - L	0.01	Not Significant

Table. 2 Means and Standard deviations of PTA, Tinnitus - SL, Tinnitus - Score, HHS, SRT, SDS, Binaural Impairment (%), PTA-B and PTA-W for the 29 male subjects.

	Mean	Standard Deviation
PTA - R	26.45	26.45
PTA - L	25.45	14.26
Tinnitus - Sensation Level	7.28	5.63
Tinnitus Questionnaire - Tinnitus Score	9.28	2.33
The Hearing Handicap Scale	59.31	12.56
Speech Reception Threshold - R	20.76	13.89
Speech Reception Threshold - L	20.28	12.38
Speech Discrimination Score - R	88.38	10.9
Speech Discrimination Score - L	88.48	11.23
Binaural Impairment (%)	6.98	12.07
PTA - Better	21.31	13.51
PTA - Worse	30.59	15.72

To evaluate the correlations between the hearing handicap and audiological measures, several characteristics of the measurement results have to be mentioned. The higher scores on the Pure Tone Average (PTA), Speech Recognition Threshold (SRT), and Binaural Impairment (BHI) indicate increasingly poor hearing; whereas, higher score on Speech Discrimination Score (SDS) indicate increasingly good hearing. The higher scores on the Hearing Handicap Scale (HHS) represent increasing degrees of hearing handicap (Highest score = 100). The higher the score on the Tinnitus - SL, the louder the tinnitus a patient perceived. Relatively high scores on the Tinnitus - Score represent increasing annoyance induced by the tinnitus (Highest score = 12).

Thus, if the subjects performed consistently on all audiological tests, the Hearing Handicap Scale would be expected to correlate negatively with the SDS and positively with the remainder of the audiological tests. Among the eleven variables, only Tinnitus - SL was moderately correlated ($r = 0.51$) with the Hearing Handicap Scale. Mild correlations were found between SDS - R, SDS - L, PTA - L, Tinnitus - Score and the Hearing Handicap Scale. Six of the audiological variables: PTA - Better, BHI (%), PTA - Worst, PTA - R, SRT - R, SRT - L do not have statistically significant correlation to the Hearing Handicap Scale.

Relationship between Severity of Tinnitus and the Degree of Hearing Handicap

A regression analysis was performed to obtain the following arithmetic formulas. These formulas were used to predict the Hearing Handicap Scale scores from Tinnitus-SL, Binaural Impairment, and Tinnitus - SL + Binaural Impairment. A weighting of five to one in favor of the better ear was used to calculate binaural hearing impairment.

a. Hearing Handicap Scale (HHS) = 1.14 (Tinnitus - SL) + 51

b. Hearing Handicap Scale (HHS) = 0.13 (Binaural Impairment) + 58.38

c. Hearing Handicap Scale (HHS) = 1.14 (Tinnitus - SL) + 0.13(Binaural Impairment) + 50.15

DISCUSSION

Relationship between Hearing Handicap and Hearing Impairment

This study is an attempt to analyze the correlation of audiological measures and severity of tinnitus to self-perceived hearing handicap in a group of 29 males who have filed claims for Workman's Compensation. Hearing handicap refers to any disadvantages and limitations imposed on a person to perform activities of daily life as a result of hearing impairment (High et al., 1964, Tye-Murray, 1998). Individuals with identical hearing levels and word recognition scores experience different degrees of hearing handicap (Tyler & Smith, 1983; Hallberg, Johnson & Axelsson, 1993). Therefore, it is incomplete and inadequate to describe the effect of an impairment on everyday function based on audiometric data alone. The self-assessment of hearing handicap has been widely used to provide information about an individual's response to hearing impairment (Weinstein & Ventry, 1983).

High et al. (1964) found that the HHS score correlated best with threshold measurements. Better ear PTA, better ear SRT and BHI correlated moderately with the Hearing Handicap Scale. The correlations were 0.65, 0.70 and 0.68, respectively. The Hearing Handicap Scale did not correlate significantly with either better or poorer ear speech discrimination measures. Other researchers have also found the correlation between pure tone sensitivity and measurements of perceived handicap as weak to moderate (Brainerd & Frankel, 1985; Lutman, Brown & Coles, 1987; Lillemor, Hallberg & Carlsson, 1991) or as strong (Tyler & Smith, 1983). These correlations confirm the fact that hearing loss as measured by pure-tone audiometry is a component of hearing handicap. However, the different results also suggest that an individual's perception of handicap is affected by nonauditory factors including health, present age, age at onset of hearing loss, communication needs, support received from others and socioeconomic status (Tyler & Smith, 1983; Weinstein & Ventry, 1983; Hallberg et al., 1993).

Contrary to the results of High et al. (1964), the PTA-Better, SRT and BHI in this study did not correlate significantly with the perceived handicap as measured by the Hearing Handicap Scale. This was an unexpected finding, since the self-administered questionnaire, The Hearing Handicap Scale, was used in both studies. A main difference between the study of High et al. (1964) and the current study was the population tested. High et al. (1964) tested a random group of subjects. The 29 workers in the present study with the mean PTA-Better of 21.31dBHL were seeking compensation for their hearing impairment. It is possible that the 29 subjects in the present study exaggerated their answers on the handicap questionnaires to convince the audiologist that they were experiencing a great deal of hearing difficulty because of their hearing impairment.

In the present study, the thresholds of PTA-Better among the 29 subjects are an accurate measurement because they are consistent with the SRT of the same ear. As the correlation analysis indicated, there is strong correlation between SRT-R and PTA-R ($r = 0.96$), and SRT-L and PTA-L ($r = 0.89$). However, the accuracy of responses on the Hearing Handicap Scale and tinnitus loudness measurement from the 29 subjects is unknown to the audiologist. There is no way to evaluate these measurement results objectively.

<u>Relationship between Tinnitus Severity and Hearing Handicap</u>

Tyler & Baker (1983) found that the three most common difficulties attributed to tinnitus were getting to sleep, persistence of tinnitus and understanding speech. Hallam, Jackes, Chambers & Hinchcliffe (1985) indicated that correlations for tinnitus measured in terms of sensation level (at a frequency where the threshold is normal with regard to hearing impairment) and hearing handicap failed to reach statistical significance ($r = 0.10$). However, the correlational analysis in the present study showed that tinnitus-sensation level was the only variable that was moderately correlated ($r = 0.51$) with the Hearing Handicap Scale for the 29 male subjects. According to a study conducted by

Newman, Wharton, Shivapuja & Jacobson (1994), it is suggested that an individual with both tinnitus and high-frequency hearing loss may have more difficulty understanding speech in a listening situation with background noise than a person with similar audiometric thresholds without tinnitus. Due to the inconsistent results across studies, further study is needed to examine the relationship between tinnitus loudness in sensation level and its effects on self-assessed hearing handicap.

Relationship between Tinnitus Severity and Hearing Loss

Chung et al. (1984) indicated that hearing level is the most important factor to be related to the loudness level of tinnitus. The higher the hearing level, the louder the tinnitus a person might perceive. This relationship does not exist in the present study. PTA - Worst does not have statistically significant correlation ($r = 0.04$) to the Tinnitus - SL.

Relationship between Tinnitus Annoyance and Hearing Handicap

Hallberg, Johnsson & Axelsson (1993) hypothesed that a high degree of tinnitus annoyance were related to high scores on perceived hearing handicap. Results showed that 36% of the variance in tinnitus annoyance was accounted for by "sleep disturbance" and "auditory perceptual difficulties". In their study, sleep disturbance and auditory perceptual difficulties were examined as combined effects contributing to tinnitus annoyance. The relationship between tinnitus annoyance and auditory perceptual difficulties was not stated in their study. Lillemor, Hallberg & Carlsson (1991) reported that tinnitus annoyance did not show a correlation with perceived handicap. However, they did not provide any data in their study that was relevant to this finding. The current study found a mild correlation between tinnitus annoyance as measured by the Tinnitus Questionnaires and the Hearing Handicap Scale scores (r = 0.23). Further studies in the are necessary to explore the relationship between tinnitus annoyance and hearing handicap.

Relationships between Two Tinnitus Measurements

Jakes, Hallam, Chambers & Hinchcliffe (1985) reported that tinnitus loudness determined by self-rated or loudness matching was unrelated to tinnitus annoyance. Contrary to this result, a moderate correlation between loudness matching measurements and tinnitus annoyance as measured by the Tinnitus Questionnaires was found among the 29 subjects (r = 0.54). Each individual responds to distress differently (Goodwin & Johnson, 1980). Some of the tinnitus-related complaint behavior could be a result of a hearing loss or other stressful life events (Tyler & Baker, 1983). Therefore, the Tinnitus Questionnaire is an inadequate measurement to verify the tinnitus loudness match.

Compensating Claimants for Tinnitus

As mentioned in the study of High et al. (1964), BHI is one of the audiological variables correlated significantly (r = 0.68) with the Hearing Handicap Scale. Based on the regression analysis in the present study, unexpectedly, tinnitus-sensation level is a more important factor than BHI in predicting hearing handicap for this group of subjects. In the formula (a) HHS = 1.14 (Tinnitus - SL) + 51, accordingly, 1dB loudness of tinnitus should obtain an HHS score of approximately 52.14. 1dB loudness of tinnitus, using formula (C), is worth approximately in 6.5% hearing impairment terms.

$$HHS = 1.14\ (\text{Tinnitus - SL}) + 0.13\ (BHI) + 50.15$$

$$52.14 = 1.14 \times 1 + 0.13\ (BHI) + 50.15$$

$$52.14 = 51.29 + 0.13\ (BHI)$$

$$BHI = 6.5\%$$

Conclusions

1. High et al. (1964) indicated that one of the limitations of the Hearing Handicap Scale is that it is appropriately used only with cooperative individuals because responses to the questions can easily be falsified. Our subjects may have had motivation to exaggerate their hearing handicap. Their workman's compensation claims depended on their proving a significant handicap. This may have caused some of the unexpected results such as the low correlation between hearing impairment and hearing handicap, and the high correlation between tinnitus - SL and hearing handicap.

2. There was no evidence from our data that more severe tinnitus was associated with more severe hearing loss.

3. The literature search did not produce a definitive study about the relationship between tinnitus annoyance and hearing handicap. Our data indicated a mild correlation between tinnitus annoyance and hearing handicap.

4. The Shulman Tinnitus Questionnaire is only moderately correlated with Tinnitus - SL. It should not be used to check the accuracy of the Tinnitus - SL.

5. Our data indicates that the hearing handicap is influenced more by tinnitus loudness than hearing loss. If a person had tinnitus equal in loudness to a 1dBSL tone, it would be equivalent to a 6.5% hearing impairment.

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Appendix (A) - Tinnitus Questionnaire

1. Do you have ringing or noises in your ears or head?

   Yes ( ) No ( )

2. Is the noise constant or intermittent?

   Constant ( ) (3) Intermittent ( )

   If intermittent, is it:
   On more than off ( ) (2)
   Off more than on ( ) (1)

3. Does it prevent you from going to sleep?

   Yes ( ) No ( )

   If yes, Frequently ( ) (2) Infrequently ( ) (1)

4. Is it worse in quiet?

   Yes ( ) No ( )

   Is it worse when you are not busy doing something?

   Yes ( ) (1) No ( ) (2)

5. What does it sound like?

   High-pitch tone ( ) (2)
   Low-pitch tone ( ) (1)
   Rushing air ( ) (1)
   Static ( ) (2)
   Etc. ( ) (1)

   How much does it bother you?

   Mild ( ) (1)
   Moderate ( ) (2)
   Severe ( ) (3)

Rating Scale

5 = Slight
6 to 7 = Mild
8 to 9 = Mild to Moderate
10 to 11 = Moderate
12 = Severe

Score:________________

Appendix (B) - Hearing Handicap Scale

Almost Always	Usually	Sometimes	Rarely	Almost Never
1	2	3	4	5

1. When you are listening to the radio or watching television, can you hear adequately when the volume is comfortable for most other people?

2. Can you carry on a conversation with one other person when you are riding in an automobile with the windows closed?

3. Can you carry on a conversation with one other person when you are riding in automobile with the window open?

4. Can you carry on a conversation with one other person if there is a radio or television in the same room playing at normal loudness?

5. Can you hear when someone calls to you from another room?

6. Can you understand when someone speaks to you from another room?

7. When you buy something in a store, do you easily understand the clerk?

8. Can you carry on a conversation with someone who does not speak as loudly as most people?

9. Can you tell if a person is talking when you are seated beside him and cannot see his face?

10. When you ask someone for directions, do you understand what he says?

11. Can you understand if someone speaks to you in a whisper and you can't see his face?

12. When you talk with a bus driver, waiter, ticket salesman, etc., can you understand all right?

13. Can you carry on a conversation if you are seated across the room from someone who speaks in a normal tone of voice?

14. Can you understand women when they talk?

15. Can you carry on a conversation with one other person when you are out-of-doors and it is reasonably quiet?

16. When you are at a meeting or at a large dinner table, would you know the speaker was talking if you could not see his lips moving?

17. Can you follow the conversation when you are at a large dinner table or in a meeting with a small group?

18. If you are seated under the balcony of a theater of auditorium, can you hear well enough to follow what is going on?

19. When you are in a large formal gathering (a church, lodge, lecture hall, etc.,) can you hear what is said when the speaker does not use a microphone?

20. Can you hear the telephone ring when you are in the room where it is located?

21. Can you hear warning signals, such as automobile horns, railway crossing bells, or emergency vehicle sirens?

Table. 3 Correlation Matrix

	PTA-R	PTA-L	TINNITUS SL	TINNITUS SCORE	HHS	SRT-R	SRT-L	SP.DIS.-R	SP.DIS.L	BINAURAL IMPAIRMENT (%)	PTA-BETTER	PTA-WORST
PTA-R	1											
PTA-L	0.69	1										
TINNITUS-SL	0.07	0.11	1									
TINNITUS-SCORE	0.08	0.04	0.54	1								
HHS	0.06	0.23	0.51	0.23	1							
SRT-R	0.96	0.69	-0.01	0.05	0.03	1						
SRT-L	0.71	0.89	-0.03	-0.11	0.01	0.75	1					
SP.DIS.-R	-0.6	-0.52	-0.29	-0.18	-0.34	-0.56	-0.4	1				
SP.DIS.-L	-0.54	-0.69	-0.18	-0.13	-0.26	-0.54	-0.61	0.62	1			
BINAURAL IMPAIRMENT (%)	0.81	0.82	0.01	-0.01	0.13	0.77	0.74	-0.56	-0.61	1		
PTA-BETTER	0.86	0.91	0.16	0.09	0.17	0.82	0.81	-0.63	-0.66	0.92	1	
PTA-WORST	0.93	0.85	0.04	0.04	0.12	0.92	0.85	-0.55	-0.62	0.8	0.87	1

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