PEER REVIEW HISTORY

ARTICLE DETAILS

TITLE (PROVISIONAL)	Real ear acoustical characteristics of impulse sound generated by golf drivers and the estimated risk to hearing
AUTHORS	Zhao, Fei; Bardsley, Barry

VERSION 1 - REVIEW

REVIEWER	Malcolm A Buchanan Specialist Registrar in Otorhinolaryngology Norfolk and Norwich University Hospital Norwich UK No competing interests to declare.
REVIEW RETURNED	20-Jul-2013

THE STUDY	The Abstract does not contain all of the subheadings stipulated in the Instructions to Authors. The p-value for the one club with higher noise levels should be included in the Results section of the Abstract. It is not clear why the Conclusions section of the Abstract mentions SPLs of 116 and 123 dBA, which do not follow on logically from the Results section of 100 and 98.2 dBA. A reference for the equation T=8/2^((SPL-85)/3) is required.
GENERAL COMMENTS	This is a very interesting and well-designed study which I enjoyed reading. I look forward to seeing the revised version. For non-audiologists, an explanation of frequency responses and why they were measured is required in the Methods section. Similarly, an explanation of the meaning of the data in Figure 2 is required. I am not sure of the relevance of the data in Table 1. Please explain why particpants' hearing thresholds were measured (presumably in dBA?). Why have the manufacturers of their clubs been listed when we are not told of the manufacturers of clubs 1-3? Is height of golfer related to swing speed? In light of the previous study (ref. 4), we are not informed which of clubs 1-3 is/are thin-faced titanium, as such clubs generate a louder impact noise. The first sentence of the Discussion implies that all three are thin-faced titanium. Figure 2 shows the SPLs for clubs 1-3, but I am not sure of the relevance of showing data for participants' own clubs as this is pooled data and therefore difficult to interpret.

	p10 para 2 'There was a significant effect for club' - should there be another word or number at the end of this sentence; similarly 'The main effect for ear...did not reach statistical significance.' Is there a missing word after 'ear'? p11 para 1 - what is club 4? Again, 'The main effect for ear...' Why is Figure 4 presented? It does not show anything of audiological relevance. Although swing speed did not correlate with loudness at a statistically significant level, it would be interesting to see a scatter plot of loudness v. speed for each club. p11 - how was sound duration measured? Explain what T1 and T are. The word 'Thus' is used, but I don't understand how the formula %=T1/T follows on. How is the figure of 2.5% obtained? Is this from the equation T=8/2^((SPL-85)/3)? Figures 5 and 6 require more explanation, in particular why there are 12 points in Fig 5 and many more in Fig 6, and what the shaded areas mean. There is no reference to Figure 6 in the text. Figure 5 refers to 'various clubs', but which ones?

REVIEWER	Greg Flamme, Ph.D. Associate Professor Department of Speech Pathology and Audiology Western Michigan University Kalamazoo, MI USA I have no conflicts of interest to declare.
REVIEW RETURNED	20-Aug-2013

THE STUDY	Re overall study design and description of methods: It is a great idea to obtain ear canal recordings to account for individual differences in ear canal resonance. However, those recordings must then be transformed into free-field equivalent values in order to be interpreted relative to an 85 dB LAeq8. If this transformation (i.e., inversion of the average field-to-eardrum transfer function) was made, this should be made clear in the paper. If not, it should be done. Also, regular reference is made to peak levels, but it is not clear that instantaneous peak levels were obtained. It seems more likely that the REM used returned maximum RMS values, where the RMS was integrated over a fixed interval (e.g., 125 ms). This distinction is important because it produces an unpredictable bias. More detail is needed on the REM and post-processing (e.g., RMS versus instantaneous peak, integration time, filtering type and bandwidth prior to assessment of overall level, procedure for deriving free-field equivalent levels). A clinical REM system would be optimized for hearing aids and not for impulse/impact noises, so it is quite possible that design decisions were made in REM development that will complicate the use of this system for the current purpose.
RESULTS & CONCLUSIONS	The results and subsequent interpretation depend on better

	specification of the method, particularly the instrumentation. I have no doubt that the results were obtained via a reasonable process, but I cannot rule out, either in the manuscript or via consulting the manufacturer, that the values obtained were flawed.
GENERAL COMMENTS	The core of this project is reasonable, but the authors need to establish that the instrumentation used is adequate for the task. Impact and impulse noise measurement is not at all simple, and it is made even more difficult when the investigator does not have access to a pressure waveform recorded at a high sample rate using signal conditioning equipment with a fast slew rate and an ample power supply. Even the class of filters used within the equipment (e.g., Bessel, Butterworth, Chebyshev) might influence the results for impact/impulse noises in ways that are unimportant for hearing aid measurements but that can have non-trivial influences on the measurement of impact/impulse sounds, and it is important to be constantly aware that the recording system is limited by the combination of supply voltage and transducer sensitivity. The FreeFit system has a stated upper limit of 130 dB SPL, and depending on the integration time of the RMS detector, the system could have been saturated at the peak during the recording process. The manuscript contains multiple typographical errors that should be corrected prior to re-submission. Minor comments have been appended to the .pdf document and uploaded.

- Reviewer 2 also provide a marked PDF which is available upon request from the publisher.

VERSION 1 – AUTHOR RESPONSE

Responses to Mr Malcolm Buchanan:

Overall comment: 'Positive feedback'

This is a very interesting and well-designed study which I enjoyed reading. I look forward to seeing the revised version.

Response:

We are delighted to hear this positive comment. We would like to thank you for the most helpful comments and suggestions.

Issue 1: 'Subheadings in Abstract'

The Abstract does not contain all of the subheadings stipulated in the Instructions to Authors. The p-value for the one club with higher noise levels should be included in the Results section of the Abstract.

Response:

Thanks for this useful comment. We found this comment is helpful and important. To further clarify this issue, we have revised the format of the Abstract section by adding all required subheadings, i.e.,

Objectives

This study investigated real ear acoustical characteristics in terms of the sound pressure levels (SPLs) and frequency responses in situ generated from golf club drivers at impact with a golf ball. The risk of hearing loss caused by hitting a basket of golf balls using various drivers was then estimated.

Design:

Cross-sectional study.

Setting:

The three driver clubs were chosen on the basis of reflection of the commonality and modern technology of the clubs. The participants were asked to choose the clubs in a random order and hit 6 two-piece range golf balls with each club. The experiment was carried out at a golf driving range in South Wales, UK.

Participants:

Nineteen male amateur golfers volunteered to take part in the study, with an age range of 19-54 years.

Outcome measures:

The frequency responses and peak sound pressure levels in situ of the transient sound generated from the club at impact were recorded bilaterally and simultaneously using the GN Otometric Freefit wireless Real Ear Measurement System (REM). A Swing Speed Radar system was also used to investigate the relationship between noise level and swing speed.

Results:

Different clubs generated significantly different real ear acoustical characteristics in terms of sound pressure levels and frequency responses. However, they did not differ significantly between the ears. No significant correlation was found between the swing speed and noise intensity. On the basis of the SPLs measured in the present study, the percentage of daily noise exposure for hitting a basket of golf balls using the drivers described above were less than 2.0%.

Conclusions

The immediate danger of noise induced hearing loss for amateur golfers is quite unlikely. However, it may be dangerous to hearing if the noise level generated by the golf clubs exceeded 116 dBA.

Issue 2: 'Unclear conclusion in Abstract'

It is not clear why the Conclusions section of the Abstract mentions SPLs of 116 and 123 dBA, which do not follow on logically from the Results section of 100 and 98.2 dBA.

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify this issue, we have amended the conclusion section completely as follows,

Conclusions

The immediate danger of noise induced hearing loss for amateur golfers is quite unlikely. However, it may be dangerous to hearing if the noise level generated by the golf clubs exceeded 116 dBA.

Issue 3: 'Need to include a reference for the equation'

A reference for the equation T=8/2^((SPL-85)/3) is required.

Response:

As requested, we have added a new reference for the equation (Page 10), i.e.,

In the present study, in order to estimate hearing risk, the damage criteria of 85 dBA for a maximum 8 hour period advocated by the National Institute for Occupational Safety and Health (NIOSH) [11], was adapted with an exchange rate of 3 dB and using the A-weighting scale. Thus, the following formula was used:

$$\textit{Daily Noise Dose}\ \% = T_1\ \text{(total exposure duration)/T (reference duration)}$$

Where T=8/2^((SPL-85)/3)

Issue 4: 'Unclear explanation of frequency responses'

For non-audiologists, an explanation of frequency responses and why they were measured

is required in the Methods section. Similarly, an explanation of the meaning of the data in Figure 2 is required.

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify this issue, we have amended this sentence in the relevant part of the method session as follows (Page 6),

Because of natural amplification of the external ear canal, for the purpose of this study, the real ear acoustical characteristics in terms of sound frequency spectrum (i.e. frequency response) and sound pressure level were investigated using a probe microphone at the position near the eardrum.

In addition, we have re-constructed the Figure 2 with clear labels and explanations.

Issue 5: 'Various unclear descriptions'

I *am not sure of the relevance of the data in Table 1. Please explain why participants' hearing thresholds were measured (presumably in dBA?). Why have the manufacturers of their clubs been listed when we are not told of the manufacturers of clubs 1-3?*

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. After re-consideration of the main focus of the present study, we have decided to delete the previous Table 1 together with hearing threshold measurement. Morever, we have added information to explain the reason not disclosing the names of manufacturers of the golf clubs (Page 6),

Golf driver clubs

The three driver clubs were chosen on the basis of reflection of the commonality and modern technology of the clubs together with consideration of their potentially high loudness levels as listed in the study by Buchannan *et al.*[4] Due to the potential commercial dispute and conflicts of interest, the names of the manufacturers of the clubs were not disclosed, and consequently these differently branded clubs were coded as Club 1, Club 2 and Club 3 in the present study. However, this information can be discussed by contacting the authors if there is any concern about the potential hazard of hearing damage to the golf players. In addition, in accordance with experimental protocol, each participant was invited to bring their own driver and use it along with three other driver clubs.

Issue 6: 'Unclear description of the club design'

In light of the previous study (ref. 4), we are not informed which of clubs 1-3 is/are thin-faced titanium, as such clubs generate a louder impact noise. The first sentence of the Discussion implies that all three are thin-faced titanium.

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify this issue, we have amended this sentence in the relevant parts of the revised manuscript as follows (Page 11),

Although a small sample of clubs was used in the present study, and therefore the findings cannot be attributed to all driver clubs on the market, it does demonstrate that there is significant variance in the output generated from thin faced titanium drivers used in the present study, showing significant differences in the intensity and frequency characteristics obtained from this Club compared with the others. It implies that golf driver clubs differ in terms of a potential risk to hearing damage.

Issue 7: 'Pooled data in Figure 2'

Figure 2 shows the SPLs for clubs 1-3, but I am not sure of the relevance of showing data for participants' own clubs as this is pooled data and therefore difficult to interpret.

Response:

Thanks for this useful comment. We completely agree with this comment on including the pooled data obtained from own clubs. As suggested, we have deleted the data and reconstructed relevant figures.

Issue 8: 'Unclear descriptions'

p10 para 2 'There was a significant effect for club' - should there be another word or number at the end of this sentence; similarly 'The main effect for ear...did not reach statistical significance.' Is there a missing word after 'ear'?

p11 para 1 - what is club 4? Again, 'The main effect for ear...'

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify these issues, we have amended the relevant parts of the revised manuscript (Pages 8-9).

Issue 9: 'unnecessary Figure 4'

Why is Figure 4 presented? It does not show anything of audiological relevance.

Response:

We completely agree with this comment. As suggested, we have deleted the previous Figure 4. Instead, the relevant data have been added to the new Table 1.

Issue 10: 'Swing speed vs. Intensity'

Although swing speed did not correlate with loudness at a statistically significant level, it would be interesting to see a scatter plot of loudness v. speed for each club.

Response:

As suggested, we did try to construct the scatter graphs of swing speed vs. intensity. As no statistical significance was found, the scatter plot appeared random data, which could not indicate any useful information. Therefore, we have decided not to include this graph in the present manuscript.

Issue 11: 'Sound duration measurement'

p11 - how was sound duration measured?

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify these issues, we have amended this sentence in the relevant parts of the revised manuscript as follows (Page 10),

Hearing risk was estimated by calculating the percentage of daily noise exposure for hitting a basket of golf balls using those drivers described above. The sound duration of striking a golf ball was measured by recording the sound waveforms from the beginning of the impulse sound until it fell away when crossing the baseline. On average, the sound duration of striking a golf ball was recorded as approximately 0.5 seconds. If hitting a basket of golf balls, which are typically 40 in number, the total sound exposure duration was 20 seconds (i.e., 0.00556 hours).

Issue 12: 'Unclear description for the formula'

Explain what T1 and T are. The word 'Thus' is used, but I don't understand how the formula %=T1/T follows on.

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify these issues, we have amended this sentence in the relevant parts of the revised manuscript as follows (Page 10),

In the present study, in order to estimate hearing risk, the damage criteria of 85 dBA for a maximum 8 hour period advocated by the National Institute for Occupational Safety and Health (NIOSH) [11], was adapted with an exchange rate of 3 dB and using the A-weighting scale. Thus, the following formula was used:

***Daily Noise Dose* %= T_1 (total exposure duration)/T (reference duration)**

Where T=8/2^((SPL-85)/3), and T_1=0.00556

Issue 13: 'Unclear description'

How is the figure of 2.5% obtained? Is this from the equation T=8/2^((SPL-85)/3)?

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. It was calculated on the basis of the following formula, i.e.,

***Daily Noise Dose* %= T_1 (total exposure duration)/T (reference duration)**

Where T=8/2^((SPL-85)/3), and T_1=0.00556

For example, if the SPL is equal to 100 dBA, the T is equal to 0.25 (hr), which means the maximal exposure duration. To calculate the total exposure duration when hitting a basket of golf balls (40 balls used in the present study), it is estimated around 20 seconds (i.e., 0.00556 hours). Then, the total daily exposure dose is 2.22%.

To clarify this issue, we have amended this sentence in the relevant parts of the revised manuscript as follows (Page 10),

Hearing risk was estimated by calculating the percentage of daily noise exposure for hitting a basket of golf balls using those drivers described above. The sound duration of striking a golf ball was measured by recording the sound waveforms from the beginning of the impulse sound until it fell away when crossing the baseline. On average, the sound duration of striking a golf ball was recorded as approximately 0.5 seconds. If hitting a basket of golf balls, which are typically 40 in number, the total sound exposure duration was 20 seconds (i.e., 0.00556 hours).

In the present study, in order to estimate hearing risk, the damage criteria of 85 dBA for a maximum 8 hour period advocated by the National Institute for Occupational Safety and Health (NIOSH) [11] was adapted with an exchange rate of 3 dB and using the A-weighting scale. Thus, the following formula was used:

***Daily Noise Dose* %= T_1 (total exposure duration)/T (reference duration)*100**

Where T=8/2^((SPL-85)/3), and T_1=0.00556.

Issue 14: 'Figures 5 and 6'

Figures 5 and 6 require more explanation, in particular why there are 12 points in Fig 5 and many more in Fig 6, and what the shaded areas mean. There is no reference to Figure 6 in the text. Figure 5 refers to 'various clubs', but which ones?

Response:

We apologise for the confusion caused by the unclear descriptions in the previous manuscript. To clarify these issues, we have reconstructed the Figure 5, and consequently amended this the relevant parts of the revised manuscript as follows (Pages 10-11),

Responses to Dr Greg Flamme:

Overall comment: 'Positive feedback'

Re overall study design and description of methods: It is a great idea to obtain ear canal recordings to account for individual differences in ear canal resonance.

Response:

We are delighted to hear this positive comment. We would like to thank you for the most helpful comments and suggestions.

Issue 1: 'Free field equivalent level'

However, those recordings must then be transformed into free-field equivalent values in order to be interpreted relative to an 85 dB LAeq8. If this transformation (i.e., inversion of the average field-to-eardrum transfer function) was made, this should be made clear in the paper. If not, it should be done.

Response:

Thanks for this useful comment. We found this comment is helpful and important. To further clarify this issue, we have revised the relevant parts, i.e., Page 10

Because the sound intensities generated by the golf clubs were recorded and measured in the ear canal, in order to compare them with the NIOSH standard, the transformation from real ear sound pressure levels to free-field equivalent values was performed according to ISO 11904-1[12] (i.e., inversion of the average field-to-eardrum transfer function).

Issue 2: 'Free field equivalent level'

Also, regular reference is made to peak levels, but it is not clear that instantaneous peak levels were obtained. It seems more likely that the REM used returned maximum RMS values, where the RMS was integrated over a fixed interval (e.g., 125 ms). This distinction is important because it produces an unpredictable bias. More detail is needed on the REM and post-processing (e.g., RMS versus instantaneous peak, integration time, filtering type and bandwidth prior to assessment of overall level, procedure for deriving free-field equivalent levels).

Response:

Thanks for this comment. We apologise for the confusion caused by the unclear descriptions in the previous manuscript. In the present study, we did not use the RMS value for the sound pressure measuring. On the basis of the GN Otometric Freefit Real Ear Measurement System, Both peak SPL and frequency response were chosen from visual inspection by the authors, and then measured directly in the real ear response curves. To further clarify this issue, we have added a paragraph and explain the data analysis procedure, i.e., on Page 7,

All recorded real ear responses were reviewed and analysed. In the present study, the peak SPL was determined as the highest point of the curve, whereas the frequency response was referred to as the point corresponding to the measured peak SPL. Both peak SPL and frequency response were chosen from visual inspection by the authors, and then measured directly in the real ear response curves.

Issue 3: 'REM system used in the present study'

A clinical REM system would be optimized for hearing aids and not for impulse/impact noises, so it is quite possible that design decisions were made in REM development that will complicate the use of this system for the current purpose.

Response:

Thanks for this comment. We considered this issue when we decided to choose this measurement system. After consulting the technical support for the manufacturer together with reviewing various references, this system is appropriate for the purpose of this study.

Issue 4: 'Possible peak clipping'

The FreeFit system has a stated upper limit of 130 dB SPL, and depending on the integration time of the RMS detector, the system could have been saturated at the peak during the recording process.

Response:

Thanks for this useful comment. Again, we considered this issue when we decided to choose this measurement system because the sound pressure level is possible to reach the saturation level (130 dB) of the system according to the study reported by Buchanan et al. (2008). However, after reviewing various references and carrying out a few pilot experiments, the results indicated that the sound pressure levels were around 90-100 dBA, which are consistent with the findings obtained from other studies (e.g., Ellis, 2009). Therefore, this system is appropriate for the purpose of this study. Furthermore, in reality, with visual inspection, the peak clipping did not happen during entire experiment.

Issue 5: 'Typo errors'

The manuscript contains multiple typographical errors that should be corrected prior to re-submission. Minor comments have been appended to the .pdf document and uploaded.

Response:

We apologise for the typo errors across the manuscript. We have examined the manuscript again and asked a native English speaker for her proof reading in the manuscript grammatical revision.

VERSION 2 – REVIEW

REVIEWER	Malcolm Buchanan ENT Department, Norfolk and Norwich University Hospital, Norwich, UK.
REVIEW RETURNED	06-Nov-2013

GENERAL COMMENTS	p3, line 2 - change 'were' to 'was'. p4 - change 'equal across ears' to 'equal across both ears'. p4 - change 'daily noise exposure less' to 'daily noise exposure of less'. p4 - add 'within the same golfer' after 'No difference was found between ears'. p4 - add 'from the ball' after 'using a sound level meter equidistant'. p4 - last sentence does not make sense. p5 - 'Golf' does not need a capital letter throughout the manuscript if within a sentence. p5, penultimate line - add 'have' after 'appeared to'. p7 - change 'Buchannan' to 'Buchanan'. p7, last senetnce does not make sense. Should it read 'were carried out in front of each participant'? p8, penultimate paragraph - change 'unit was position' to 'unit was positioned'. p9, penultimate line - change 'abd' to 'and'. p10, 1st para, last line - change 'Club 1 was' to 'Club 1 were'. p12, Discussion - change 'from this Club' to 'from this type of club'. p12 , Discussion - add 'dB' after '90.0'. p12, Discussion - change 'consistent with one' to 'consistent with'

	and 'which shows' to 'which show'. p13, 2nd para - add 'et al' after 'Buchanan'. p15, last 2 sentences, 2nd para - explain why despite both ears facing directly onto impact sound sources, one side of the ear is overly exposed - the two sentences contradict each other. p15 - explain the trampoline effect. Figures 2&3 - a best fit line with correlation coefficient and p-value would be beneficial. Figure 4 - what are the axis labels? What do the arrows mean? What does the golf ball icon mean?

VERSION 2 – AUTHOR RESPONSE

Responses to Mr Malcolm Buchanan:

Issue 1: 'Grammar and spelling errors'

Response:

We apologize for the grammatical errors across the manuscript. Thank you very much for your thoroughly editing the manuscript. It is very helpful. We have revised all corrections as indicated. In addition, we have examined the manuscript again and asked a native English speaker for her help in the manuscript grammatical revision.

Issue 2: ‘Unclear sentence on Page 4’
p4 - last sentence does not make sense.
Response:
We apologise for the confusion caused by the unclear description in the previous manuscript. To clarify this issue, we have amended this sentence as follows (Page 4),

Only three golf clubs were examined, and a relatively small sample of participants was recruited in the study.

Issue 3: ‘Unclear explanation of asymmetrical noise exposure between the left and right ears’
15, last 2 sentences, 2nd para - explain why despite both ears facing directly onto impact sound sources, one side of the ear is overly exposed - the two sentences contradict each other.

Response:
We apologise for the confusion caused by the unclear descriptions in the previous manuscript. What we would like to discuss was some controversy about asymmetrical noise exposure between the right and left ears during shooting noise exposure. It is relevant to the measurements obtained from the present study, indicating no significant difference in sound intensity between the recordings from the near and far ears.

To clarify this issue, we have amended the relevant part in this session as follows (Page 15),
In the present study, the results did not show evidence of a head shadow effect insofar as there was no significant difference in sound intensity between the recordings from the near and far ears. There

is some controversy about asymmetrical noise exposure even though both ears are exposed directly to impact sound sources. (8,18,19,20) Some previous studies argued that left ear noise-induced hearing losses are predominantly common in the army, because the ear opposite to the dominant hand sustains over exposure mainly due to the shooting posture. [18,19] However, a recent study on hearing performance after recreational firearm use did not reveal a significant preference in terms of temporary threshold shift between ears, irrespective of the dominant hand.[8] The other study by Job et al. [20] showed that the asymmetry of hearing thresholds between the left ear and right ear was not associated with the subject's shooting posture. They suggested that it is most likely due to different intrinsic characteristics in each side of the ears.

Issue 4: 'Unclear explanation of trampoline effect'
p15 - explain the trampoline effect.

Response:
As requested, we have added the definition and amended the relevant part of this session accordingly (i.e., Pages 15-16),
It is noteworthy that another important factor is the area of the club face hitting the ball to create an impact because the face of the driver club has a 'sweet spot' where the trampoline effect is optimal. The trampoline effect refers to a pronounced deformation of the club face upon impact followed by a quick restoration to its original dimensions, acting like a slingshot. When the club face hits the ball right on the sweet spot, it results in very high ball speeds. In the present study, it is impossible for the participants to control this factor in order to deliver the same performance with each strike.

Issue 5: 'Adding correlation lines for Figures 2 and 3'
Figures 2&3 - a best fit line with correlation coefficient and p-value would be beneficial.

Response:
As requested, we have added the correlation lines in Figures 2 and 3. In addition, we have also amended the relevant parts in the results session accordingly.

Issue 6: 'Unclear description/labels in Figure 4'
Figure 4 - what are the axis labels? What do the arrows mean? What does the golf ball icon

Response:
We apologise for the careless errors in the previous manuscript. As requested, we have amended this figure by adding axis labels and new figure legends.