Impact of Strong Sound of Starting Guns on the Hearing Loss of Track and Field Athletes Based on Brainstem Auditory Evoked Potential

Xinbao Wang*, Xuemin Zhao

ABSTRACT
To explore the impact of the sound of starting guns on the hearing of track referees (starters); to measure and study the noise characteristics of the muzzle and ear when track referees issue the order. The survey, ear routine examination, pure tone audiometry and brainstem auditory evoked potential were applied to conduct the audiometric test analysis and auditory function test on 20 sports college students (40 ears) and 10 college teachers (20 ears) engaged in the starting work in different time period before and after (before starting, 3h and 8d after starting) the starting (instantaneous strong noise). Under the noise intensity of 158~156 dB(Lp), the pure tone average threshold, high pure tone average threshold and I wave latency of BAEP of left and right ears 3h after the starting were significantly higher than those before the start (P<0.01). After 8 days, it gradually returns to the level before the starting. The auditory condition of teachers who regularly engage in the starting work is significantly different from that of ordinary people (P<0.01). For those who are exposed to the high-intensity noise of the starting gun for the first time, it may cause the reversible recoverable damage of hair cells of the ear and temporary threshold shift.

Key Words: Track and Field Athletes, Brainstem Auditory Evoked Potential

Introduction
Brainstem Auditory Evoked Potential (BAEP) refers to the potential changes recorded on the scalp that represents the auditory nerve, pons-medulla oblongata junction, pons, and midbrain electrical activity after the ear is given proper sound stimulation (Chang et al., 2010). Since 1970, foreign scholars have fully described the brainstem auditory evoked potentials of human beings for the first time, people have carried out more in-depth studies on BAEP in succession. Nowadays, brainstem auditory evoked potentials have been widely used in neurological clinical examination and become one of the supplementary means of neurological examination. Studies have shown that non-neurological disease factors influencing the brainstem auditory evoked potentials are various, such as temperature, age, gender, and listening competence. Recent studies have shown that sports have a certain impact on BAEP, but the research results of the influencing rule and the existence of project characteristics of different scholars are not consistent or even contradictory. By comparing various indexes of BAEP of rowing athletes, tennis players and ordinary people, it is pointed out that the peak interval of III-V is obviously shorter for both males and females than for those who do not exercise. Other studies have shown that the BAEP latency period of the ball game majors is significantly longer than that of the control group; another study shows that...
when cycling athletes and ordinary people perform extreme exercise, there is no significant difference of each index of the BAEP between these two groups when the body temperature returns to the quiet level (Lindsay et al., 1990). In order to further explore the influencing law of exercise on various indexes of BAEP so as to apply it to the functional evaluation of sports training, this paper uses the electric neurodiagnostic instrument to conduct the horizontal comparison study on various indexes of brainstem auditory evoked potentials of track and field students and ordinary students.

In recent years, with the continuous improvement of urbanization and industrialization, various kinds of noise sources have emerged and the damage on human beings is also increasing. The incidence of noise-induced deafness has increased year by year and the prevention and cure of noise induced deafness have become an important issue for scholars in various countries. It has become a hot spot for scholars from all over the world to increase the potential ability of noise resistance of noise contactors and to prevent and reduce the stimulation of noise on human ears. In addition to deafness, noise can induce various diseases such as headaches, brain swelling, tinnitus, insomnia and malaise; noise can also increase the incidence of gastrointestinal diseases and ulcers; noise also exerts negative impact on the cardiovascular system (Soldner et al., 2001). Long-term exposure to high noise will lead to the deteriorating of health levels, weakened body immunity, thus increasing the incidence of some diseases. At present, there are about 600 million people in the world working in harmful noise environment and about 10% of workers in developed countries suffer from noise-related diseases. About 10 million people in the United States have permanent hearing impairment caused by noise and trauma (Su et al., 2004).

The sound of starting guns is a strong noise that track and field referees (starters) are exposed to. There are relatively few domestic reports about the impact of strong impulse noise from the starting gun on the hearing impairment of professional people. To study the impact of the sound of starting gun on the hearing loss of starters, this paper conducts audiometric analysis and research on 20 students in Henan Normal University students and 10 college teachers who have been long engaged in the starting work of track and field. This paper also conducts first test analysis and research on the characteristics of the instantaneous strong sound at a fixed distance in the workplace of track referees (starters) and studies the influencing rule of the strong sound of the starting gun on track referees (starters).

**Methods**
The neurology department and otolaryngology department are randomly selected for the physical examination and 20 males (A group of 40 ears) with normal bilateral external auditory canal and tympanic membrane are selected to participate in the starting work, excluding cases of history of detonation, history of disease in the middle and external ears, history of conduction deafness, history of neurological deafness, history of deafness induced by ototoxic drugs, whose age is 19.5 ± 1.8 years old. In addition, 10 college teachers (group B) who have undergone the same physical examination are selected as research subjects. Their age is 34.26±7.15 years and have engaged in the starting work for 12.87±8.07 years.

Test instrument: 4 5.6 mm FL-VI type starting devices produced by Global brand (Xincheng industrial co. LTD. In Xuchang City, 600 5.6 mm starting cartridge produced by Double Ring (Chongqing Yangtze River Electric Factory), 1 starting smoke screen, AD40-2 audiometer (Denmark), B&K PULSE multi-channel noise and vibration measuring instrument, B&K 4228 calibrator, 1/4 in. measuring sensor (Denmark), Neuropack(R) MEB-5200 evoked potential meter.

The B & K PULSE multi-channel noise and vibration meter, B&K 4228 calibrator and 1/4 in. measurement sensor are used to measure the intensity of the high-intensity sound sources. The noise frequency range of the starting gun and the pulse duration are measure at the muzzle (20 cm from the test instrument) and at the ear (75 cm from the test instrument) of the starting gun. Meanwhile, the spectral energy and noise intensity at the ear and muzzle are also measure.

**Results and discussion**

**Noise intensity**
Test results at the muzzle (20 cm): the acoustic image formation is cellular state (Figure 1), which may be due to the fact that this range is influenced by sonic impinging air flow (ultrasonic velocity), leading to some non-linear phenomena. Spectral energy is mainly concentrated in the range of 53 Hz to 7 kHz (Figure 2),
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Figure 1. Time domain measurement result (20cm from the gunpoint)

Figure 2. 1/3 octave SPL spectrum (20 cm from the gunpoint)

Figure 3. 1/3 octave SPL spectrum (75 cm from the gunpoint)

with a maximum of 115 dB at 2.5 kHz and a total sound pressure level of 124 dB (Lp). The maximum of the time-domain test result is 158 dB and the pulse width is about 60 ms.

General examination results

There were 34 cases (ears) of tinnitus 3 hours after the firing in group A and 8 cases (ears) of tinnitus 8 days after the firing; 13 people had a significant hearing loss 3 hours after the firing and 7 people did not feel the hearing loss. 20 people had a fullness feeling inside the ear, and the average duration is 5?2.3h. In Group B, 13 cases (ears) of tinnitus were detected (Table 1).

After the firing, all subjects had different degree of bilateral tympanic membrane hyperemia (Table 1), and the average duration was 6 to 2.1 days. College teachers did not use noise reduction devices when working as track and field referees (starters).

Group A: the average value of pure tone PTA and high tone HPTA before the firing were 7.75±3.50 dB(L) and 7.17±3.67 dB(R) respectively, 7.58 3.23.25 dB(L) and 7.16±3.10 dB(R), which is within the normal range, indicating normal hearing. The average value of pure tone PTA and high tone HPTA before the firing were 25.08±12.70 dB (L) and 28.62±10.52 dB(R), 36.41±14.87 dB (L) and 41.33±15.15 dB(R). The average hearing threshold significantly increased in both ears and there was a very significant difference from the value before the firing (P<0.001). The average value of pure tone PTA and high tone HPTA before the firing were 8.25?3.28 dB(L) and 9.00±4.06 dB(R), 14.58?7.90 dB(L) and 15.67?8.76 dB(R). The PTA basically returned to the level before the firing (P>0.05). There was a significant difference of HPTA between the value before the start (P<0.01), but the hearing loss gradually recovered (Table 2) (Geal-Dor et al., 1993).

Table 1. Aural buzz, self-conscious auditory capacity and checked with the aural mirror of A Group (including before firing and after firing) and B Group

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Total</th>
<th>Feeling bulging</th>
<th>Hearing loss</th>
<th>Eardrum hyperemia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No tinnitus</td>
<td>tinnitus</td>
<td>obvious</td>
<td>Not obvious</td>
</tr>
<tr>
<td>Group A before the start</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A Issued 3d</td>
<td>40</td>
<td>6</td>
<td>34</td>
<td>40</td>
<td>26</td>
</tr>
<tr>
<td>Group A Issued 8d</td>
<td>40</td>
<td>32</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>40</td>
<td>7</td>
<td>13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Results determined with pure sound of A Group (including before firing, 3 hours and 8 days after firing) and B Group

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>Group A before the start</th>
<th>Group A issued 3d</th>
<th>Group A issued 8d</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>left</td>
<td>right</td>
<td>left</td>
<td>right</td>
</tr>
<tr>
<td>500</td>
<td>8.25±3.73</td>
<td>6.5±2.86</td>
<td>23.25±9.36</td>
<td>27.75±11.06</td>
</tr>
<tr>
<td>1000</td>
<td>8.50±3.67</td>
<td>7.25±3.80</td>
<td>24.5±11.46</td>
<td>29.50±10.37</td>
</tr>
<tr>
<td>2000</td>
<td>6.50±2.86</td>
<td>7.75±3.43</td>
<td>27.75±10.69</td>
<td>30.75±10.62</td>
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<tr>
<td></td>
<td>left</td>
<td>right</td>
<td>left</td>
<td>right</td>
</tr>
<tr>
<td>PTA</td>
<td>7.75±3.50</td>
<td>7.17±3.67</td>
<td>25.08±10.70</td>
<td>28.62±10.52</td>
</tr>
<tr>
<td>4000</td>
<td>7.75±3.02</td>
<td>6.72±2.45</td>
<td>30.25±15.32</td>
<td>44.25±15.58</td>
</tr>
<tr>
<td>6000</td>
<td>8.25±3.72</td>
<td>7.25±3.02</td>
<td>37.75±15.68</td>
<td>40.75±14.62</td>
</tr>
<tr>
<td>8000</td>
<td>6.75±2.93</td>
<td>7.50±3.80</td>
<td>33.25±13.79</td>
<td>38.00±15.34</td>
</tr>
<tr>
<td>HPTA</td>
<td>7.58±3.25</td>
<td>7.16±3.10</td>
<td>36.41±14.87</td>
<td>41.33±15.15</td>
</tr>
</tbody>
</table>

The average value of pure tone PTA in group B was 15.00±6.56(L) and 17.17±5.36(R) and there was a very significant difference from the hearing threshold of pure tone PTA of 7.75±3.50(L) and 7.17±3.67(R) before the firing in group A (P<0.01). The average value of high tone HPTA in group B was 31.00±10.03(L) and 35.67±12.51(R) and the high tone threshold significantly increased. There was a very significant difference from the hearing threshold of high tone HPTA of 7.58±3.25(L) and 7.16±3.10(R) in group A (P<0.001) (Table 2) (Eggermont, 1992).

Brainstem auditory evoked potential results

Group: the I wave latency before the firing was 1.63±0.14 ms(L) and 1.65±0.11 ms(R); the III wave latency was: 3.79±0.14 ms(L) and 3.80±0.15 ms(R); the IV wave latency was 5.83±0.12 ms(L) and 5.83±0.11 ms(R); the I wave latency 3h after the firing was 3.93±0.18 ms(L) and 1.99±0.19 ms(R), which was a very significant increase compared to 1.63±0.14 ms(L) and 1.65±0.11 ms(R) of group A (before the firing) (P<0.01); the III wave and the IV wave latency were: 3.91±0.18 ms (L) and 3.96±0.13 ms (R), 5.96±0.20 ms (L) and 6.00±0.20 ms (R), which increased compared with that before the firing, but the increase was not significant. The I wave latency 8d after the firing was: 1.71±0.13 (L) and 1.74±0.16(R), which was also different from that before the firing. However, like the audio threshold, the latency gradually recovered. The hearing nerve conduction route is shown in Figure 4.

Figure 4. Hearing noise conduction pathway

Group B: the I wave latency was 1.80±0.16 ms (L) and 1.88±0.13 ms (R), which was a very significant difference compared to 1.63±0.14 ms (L) and 1.65±0.11 ms (R) of group A (before the firing) (P<0.01).

Conclusion and outlook

The impact of noise on auditory function is closely related to noise exposure time, noise nature and intensity, which is mainly reflected in decreased auditory sensitivity, increased threshold, poor language acceptance and signal discrimination ability. Noise can cause direct damage to the round window, basement membrane and cap membrane, disrupting hair cell and supporting cell structure, and abnormal stereocilium structure (Kraus et al., 1990). Strong pulse noise and tremor are an acute trauma. The variation of spectral peaks of high-intensity noise is significant and lasts only 1.0-2.0 ms, which can destroy the auditory sensitivity (Rogers et al., 1989).

This research found that the pressure, density, and particle velocity of the gas at the muzzle were influenced by the explosion of starting cartridge, leading to sudden fault of change. The acoustic wave pattern formed a shock wave state with a maximum of 158 dB in the time domain. The spectral energy was mainly concentrated at 53 Hz~8 kHz, with a maximum at 2.58 kHz. The total sound pressure level was 124 dB (Lp). However, there was a certain distance from the ear, so the ear was not affected by the shock wave. Acoustic reflections also had a certain effect on the test results, but these effects are negligible compared to pulsed sound. The shock wave state from the muzzle of the strong sound of the starting gun attenuated into a linear acoustic state when reaching the ear (the change of sound wave characteristics at 75 cm distance was significant, which needed to be further studied). The attenuation of time domain was 2Db; the maximum value was 156Db; the maximum peak frequency at 2.5 kHz attenuated from 115 dB to 108 Db; the spectral energy was mainly
concentrated in the 250Hz ~ 8kHz; the total sound pressure level was 118 dB(Lp). The octave analysis results (CPB, average time 2s) showed that the average 1/3 octave center frequency at the muzzle (20cm) was 119dB in 2s.

Through the intensity of high-intensity sound of the starting gun, the noise intensity data of referees (starters) at the starting work is firstly determined, which is 156 dB (A) at the ear and 158 dB (A) at the muzzle. The spectral energy at the ear and the muzzle reached its maximum in the frequency range of 2.5 kHz.

References


