Heart Rate Response of Professional Musicians When Playing Music

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Objectives: The primary aim was to determine the level of physiological stress evoked while playing music in a standing position as indicated by heart rate (HR) response. A secondary aim was to analyze the effect of music genre (classic rock, western, contemporary Christian, and metal rock) on the relative HR response. Lastly, we considered potential physiological initiators of the music-playing-induced HR response. **Methods:** HR response was monitored in 27 professional musicians (3 women, 24 men) between the ages of 21and 67 yrs old during rehearsal and public performances. The percent maximal HR (%MHR) evoked was determined by taking a percentage of the age-predicted maximal HR for each musician and comparing the average %MHR in each genre during public and rehearsal events. The role of the potential initiators of these responses (e.g., number of years playing in public, event type, instrument type, tempo, etc.) was determined using multiple regression analyses. **Results:** The overall average %MHR responses were 52±5% and 59±5% during rehearsal and public performances, respectively, with genre type having a significant effect on the HR response (p=0.01). Body mass index and tempo were each found to be significant contributors to the HR response while playing music (r^2=0.506, p=0.001). **Conclusion:** Playing music professionally evokes considerable increases in HR response, with music genre influencing the level of the physiological response. We concluded that 50% of the HR response while playing music was associated with body mass index, music tempo, and instrument type.
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Approximately 176,000 professional musicians and vocalists are employed as performers whether on stage, on-air broadcasting, or for sound and video recordings in the US.[1] Even with this number of participants, there are few studies investigating the physiological demands of music playing. Previous literature in seated orchestral musicians has shown increases in heart rate (HR), blood pressure, and respiration rates during rehearsal and concert performances.[2–4] For instance, Iñesta et al.[2] observed an elevated HR response in seated orchestral musicians during both rehearsal (60.2% maximal HR) and concert performances (76.8% maximal HR), with significantly higher responses seen in concert performances than rehearsal. Despite the musicians being seated while playing music, these observed HR responses correspond to moderate to heavy intensities as established by the American College of Sports Medicine (ACSM).[5] In addition to HR, the Compendium of Physical Activities also provides some data that describe the physiological response in terms of metabolic cost (i.e., metabolic equivalents, METs) of playing certain types of instruments.[6] However, the MET values provided in the Compendium generally underestimate the workload intensities of playing music observed in the study by Iñesta et al.[2,6] The lack of sufficient data in addition to outdated sources to support the data in the Compendium justifies further research regarding the true physiological demand of playing music.

A variety of factors could elevate HR response during musical performance (e.g., standing[7]). While orchestral musicians are normally seated during performance, in many genres (e.g., rock and roll) the performers stand. Given the elevated HR response demonstrated in seated orchestral musicians,[2] the addition of standing while playing may add additional physiological demands. Furthermore, the weight of a given instrument while standing may require additional muscular recruitment, thereby yielding a greater metabolic cost. The Compendium provides MET values for a few instruments (i.e., trombone, trumpet, horn, and double bass) in a standing position, but it is unclear how these values were obtained or if they differ from a seated position.[8] The trombone was the only instrument suggested to yield a metabolic cost above a light intensity workload (3.5 METs). Unreported factors, including instrument weight and subject characteristics (e.g., body weight, age), and playing environment (e.g. hot, humid, indoor/outdoor event) may influence physiological responses in conjunction with postural factors.

Therefore, the primary purpose of this study was to determine if playing music in genres in which the upright position is prominent evoked a significant physiological response as measured by HR responses. A secondary purpose was to determine if the physiological responses differed in musicians performing different genres of music, such as classic rock, metal rock, western, and contemporary Christian music. Lastly, a tertiary purpose was to determine potential initiators of the HR response while playing music.

METHODS

All testing and methods were approved by the Texas A&M Institutional Review Board (IRB2013-0019). Profes-

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TABLE 1. Musician Demographic Data

	No.	Age (yrs)	Years Playing	BMI (kg/m^2)	Exercise Participation*
Overall	27	39 (±14)	20 (±14)	27.2 (±5)	19/27 (70%)
Male	24	42 (±11)	22 (±13)	27.8 (±5)	—
Female	3	40 (±14)	23 (±17)	22.5 (±3)	—
Genres					
Classic rock	11	47 (±11)	24 (±13)	31.9 (±8)	8/11 (73%)
Hard rock	4	28 (±2)	9 (±6)	30.2 (±4)	2/4 (50%)
Western	6	49 (±20)	31 (±17)	24.6 (±5)	5/6 (83%)
Contemporary Christian	6	27 (±7)	17 (±6)	24.7 (±4)	4/6 (67%)

Data given as mean ± SD.
* Met ACSM standards/did not meet ACSM standards. Exercise participation questionnaire based on the most current exercise guidelines by ACSM.

sional musicians were recruited by personal invitation by the investigators and included 3 women and 24 men between ages 21and 67 years (Table 1) from various musical genres including classic rock (*n*=11), metal rock (*n*=4), western (*n*=6), and contemporary Christian (*n*=6) bands. Musicians younger than age 18 were excluded from participation, and those with a history of heart conditions (e.g., chronic heart failure) and/or taking drugs that would affect HR were excluded from the analysis (*n*=1). Given that the musicians included in our study were predominantly male with an inadequate number of females for statistical power, the sex differences in HR response were not analyzed.

The Physical Activity Readiness Questionnaire (PAR-Q) was administered to all participants pre-testing to identify individuals with a previous or current history of heart disease that might have altered HR responses, independent of playing music. In addition, all musicians completed a demographic questionnaire related to their musical and exercise history.

HRs during rehearsal and performances were monitored using a Polar Team 2 Heart Rate Monitoring System (Polar Electro Inc., Lake Success, NY), which allowed remote, wireless monitoring. All participants wore a HR monitoring chest strap during each monitored session (e.g., rehearsal and public performances) if there was no interference with instrumental output or individual performance. Resting HR values were not obtained before data collections due to non-optional conditions (e.g., loading of musical equipment) that did not allow for an accurate analysis to determine if responses obtained during musical performance differed significantly from rest.

We found that the monitoring system interfered with guitarists (i.e., both bass and normal guitar) that employed single-coil pick-ups. These guitarists' data (*n*=3) were either not collected or excluded from this study. Otherwise, HR data were collected by a small (2.5 × 1.5 inch, <20 g) transmitter on a chest strap held against the musician's skin over the sternum. HR recording was started at the beginning of the first song and was monitored continuously throughout the rehearsal/performance until the end of the last song. The HR response for each musician was determined using the average HR response within a given song as well as an average HR during the overall performance. For comparison, the HR responses described in this study are represented as a percentage of the musicians' age-related predicted maximal HR which was calculated using the widely accepted formula –220–age=estimated maximal HR.[5] The average HR response (both during individual songs and across the whole performance) was divided by the age-predicted maximal HR prediction to result in the percentage of maximal HR (%MHR).

During the data-gathering sessions, we also measured each song's tempo using a metronome (Pro Metronome, EUM Lab) and collected environmental data including temperature and relative humidity of the rehearsal/performance environment. Additionally, each subject's fluid consumption and type of fluid consumed during rehearsal/performance, as well as other stimulating substances (e.g., cigarettes) were noted. The musicians were categorized into five types of instrument groups: string, wind, keyboard/piano, vocal, and drums.

We were not able to obtain HR data for both rehearsal and public performances of all participating bands due to either conflicting schedules or musical instrument interference with HR monitor transmitters. Of the bands in this study, we obtained HR data during rehearsal and performances for the classic rock and contemporary Christian bands. We were unable to obtain HR data from the western band (*n*=6) during a rehearsal and the metal rock band (*n*=4) during a public performance. The western band was in their prime season of public performances (7 per week), and a rehearsal session was not possible during our data collection time period. For the metal rock band, HR monitoring during a public performance was not possible because of interference with the bass and guitar output. Although not included in our analysis of public performance data, we did collect HR data on the metal rock drummer during both rehearsal and public performances and present that separately (Appendix 1).

TABLE 2. Performance Data by Genre

	No.	Avg. %MHR		Avg. Tempo		Temperature	
		Rehearsal	Public Performance	Rehearsal	Public Performance	Indoor Venue	Outdoor Venue
Overall	27	52±5%	59±5%	116±16	100±16		
Male	24	52±5%	60±12%	—	—		
Female	3	NA	56±4%	—	—		
Genres							
Classic rock	11	58±6	63±6	117±12	111±22	72°	52°
Hard rock	4	69±14	NA	138±31	NA	92°	95°
Western	6	NA	62±5	NA	96±43	55°	NA
Contemporary Christian	6	47±7	52±9	94±23	92±20	72°	72°

Data given as mean ± SD.

Data were analyzed using Prism (GraphPad Software, La Jolla, CA) and SPSS (IBM-SPSS, Armonk, NY) statistical programs. To determine if there was a significant difference of the average %MHR response between rehearsal and public performances, a paired *t*-test was employed for each genre in which we were able to obtain both rehearsal and public performance HR data (i.e., classic rock and contemporary Christian genres). Differences of the average %MHR between the genre types were determined utilizing a two-way ANOVA. In the event of a significant main effect, a Tukey's post-hoc test was used. The alpha value was set *a priori* at 0.05. A multiple regression analysis (alpha=0.05) of the average %MHR for each song within each musician was used to determine the relationship of any potential initiating variables on the %MHR response.

RESULTS

The overall mean %MHR during rehearsal and public performances (Table 2) was found to be 52±5% and 59±5%, respectively. Given the lack of resting HR values in this field-based study, it cannot be determined if these HR responses during music playing were significantly elevated from rest. However, the %MHR values observed during playing are noteworthy in that they match values equivalent to moderately intense workloads of exercise (50–65% MHR),[5] thus suggesting a significant physiological stress response was evoked while playing music.

Comparing the overall mean %MHR responses did not reveal a significant difference between the rehearsal and public performances (p=0.40). To determine if this response differed by genres, post-hoc analysis was done. It showed that in the contemporary Christian band, the overall mean %MHR differences of the musicians were insignificant between rehearsal and public performance (p=0.73, Fig. 1A). However, in classic rock musicians, there was a significant increase (p=0.02) in the mean %MHR of each musician during public performance as compared to rehearsals (Fig. 1B). Two musicians from the classic rock band were excluded from the analysis in Figure 1 due to medication use (Allegra-D)[9] and a lack of the rehearsal data.

To further determine the effect of genre on the HR response while playing music, group comparisons of the overall %MHR response were analyzed. During rehearsal (Fig. 2A), a significant overall effect was observed (p=0.008), with post-hoc analysis revealing significantly higher %MHR responses of metal rock than contemporary Christian musicians (p=0.008). During public performances (Fig. 2B), the contemporary Christian musicians also exhibited lower %MHR responses than the classic rock (p=0.01) and/or western musicians (p=0.003).

A multiple regression analysis (Table 3) of the potential HR initiators on %MHR revealed a significant contribution of body mass index (BMI) (p=0.0001) and tempo (p=0.013) to the HR response during music playing, with a non-significant trend (p=0.066) due to instrument type. The analysis suggested that BMI, tempo, and instrument type collectively accounted for approximately 50% of the average overall increase in the %MHR responses among all musicians (r^2=0.506; Table 3) during music-playing. The event type (p=0.085), number of years playing (p=0.156), genre (p=0.888), previous exercise participation (p=0.288), and temperature of the performance venues (p=0.389) did not have significant effects on the HR responses while playing music.

DISCUSSION

This study examined the physiological responses evoked by professional musicians performing while standing in the genres of classic rock, contemporary Christian, western, and metal rock. Overall, we observed that musical performance, regardless of genre, evoked a significantly elevated HR response ranging from 52 to 59%, which would classify music playing as moderately intense work effort. We observed that the classic rock musicians had significantly higher HR responses during public performances when compared to rehearsals (p=0.02), while the HR responses of the contemporary Christian musicians did not vary significantly between performance types (p=0.70). Furthermore, the contemporary Christian musicians also demonstrated the lowest overall average %MHR responses

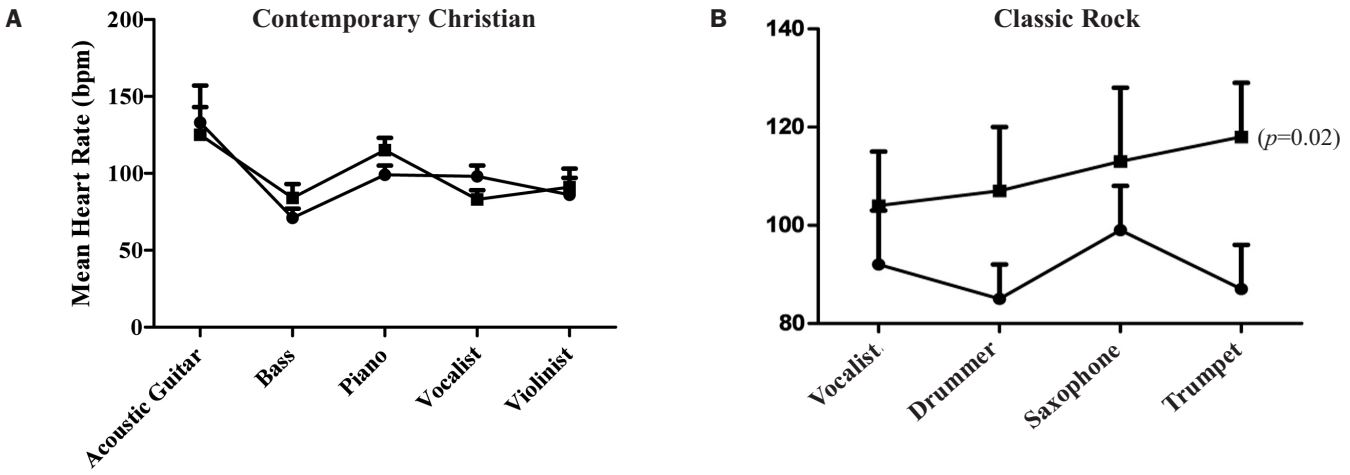

FIGURE 1. Average HR responses (in bpm) in rehearsal (*circles*) vs public performance (*squares*) for contemporary Christian musicians (*panel A*) and classic rock musicians (*panel B*). Data given as mean ± SD.

when compared to classic rock (p=0.01) and western (p=0.003) musicians during public performances and to metal rock (p=0.008) musicians during rehearsals. Considering the elevated HR responses evoked during music playing in most genres, we found the music tempo, BMI, and instrument type were all positively associated with the HR response to music playing, suggesting the physiological responses observed in our study and others[2,10] were primarily attributable to both music-intrinsic (tempo and instrument) and music-extrinsic (BMI) factors that might influence the HR response.

While most of the literature in this area has focused on the impact of psychological factors (e.g., stage fright) on the physiological responses of playing music,[4,11,12] other extrinsic variables (e.g., BMI, exercise participation, medical history, etc.) have yet to be fully examined with regards to their effect on the physiological response in the professional musician. In this study, we found that BMI, song tempo, and to a lesser extent, instrument type, accounted for 50% of the music-induced HR response. Song tempo has been previously shown to correlate with the HR response while playing music, as well as in music listeners.[10] Our data further demonstrated an effect of music tempo on the HR response, with music genres having higher tempos generally showing higher overall average %MHR in those musicians than those playing lower tempo rates (Table 2).

An additional factor known to influence physiological responses when playing music is the type of musical instrument played.[13–15] Previous studies have shown that instrument-specific technical and mechanical requirements, in addition to the weight of the instrument, may alter certain physiological responses, whether through alterations in HR,[16] HR variability,[13] energy expenditure,[6] or altered respiratory patterns.[16] For example, energy expenditure (average 1.8 METs) among wind instrumentalists is not sugges-

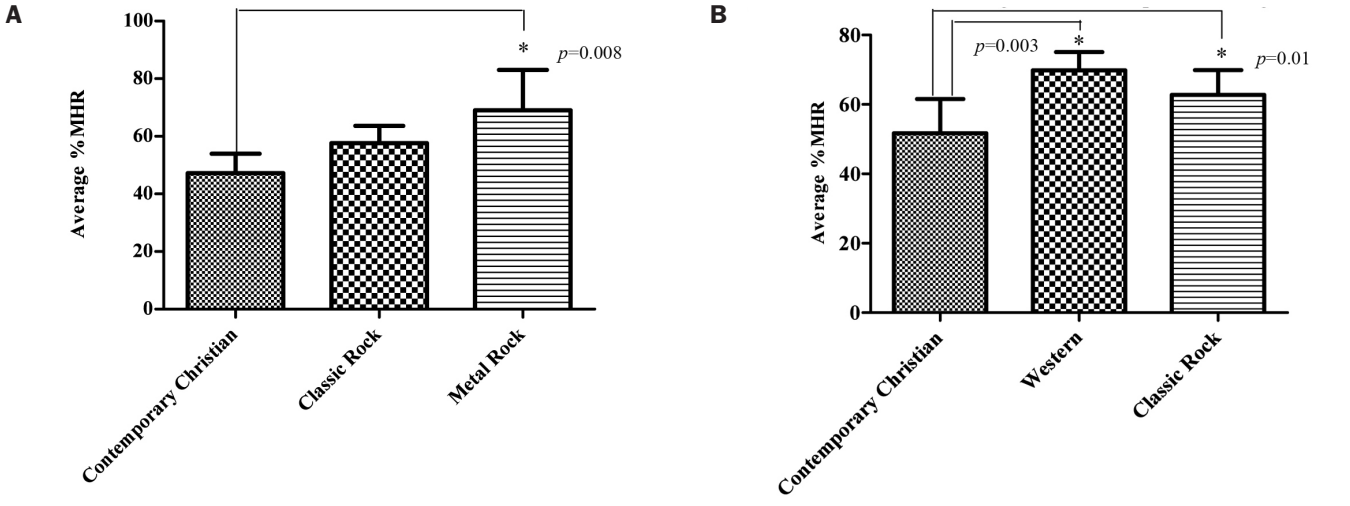

FIGURE 2. Comparison of the overall average %MHR responses during rehearsal (*panel A*) vs public performances (*panel B*) by musical genre. Data given as mean ± SD.

tive of high workload intensity,[6,17] though the fatigue represented through subjective reports and corresponding HR responses suggest otherwise.[18] Additionally, techniques unique to wind instrumentalists, such as circular breathing and/or using the Valsalva maneuver to increase wind force,[13–15] have demonstrated significant physiological alterations with increases in HR and decreases in high frequency HR variability.[13] Supporting this suggestion, other investigations have noted elevated physiological responses when musicians play wind instruments designed to play higher notes (e.g., tenor tuba) with physiological responses (e.g., HR and blood pressure) similar to those elicited during a Valsalva maneuver.[16] While the contribution of instrument type to HR responses in our regression model was not significant (p=0.066), there was a trend toward instrument type playing a role in determining HR responses, as demonstrated by a slight decrease in model fit (r^2=0.506 with instrument and r^2=0.496 without instruments) when instrument type was left out of the model.

Extrinsic to the music itself, we observed that BMI was a significant contributor to the HR response while playing music. It is well known that excessive body weight increases the workload of the heart, particularly when standing and/or performing increased physical movements.[5,7,19] Thus, a higher BMI likely further increased the physiological stress response in musicians performing and standing for long lengths of time (up to 4 hrs), performing high rates of physical movements (e.g., drumming), and/or holding heavy instrument throughout performance (e.g., trombone). For example, the drummer from the metal rock band (BMI 32 kg/m^2) revealed the highest overall average and peak %MHR values (95% and 104%, respectively) during musical performance. While this example is confounded because the metal rock band also played the songs with the highest tempo, nonetheless higher BMI values may account for further increases in the music-induced stress response for musicians, especially those who perform in a standing position as opposed to seated.

Lastly, our final aim was to determine if the overall mean % MHR varied significantly among the musical genres analyzed. Determining whether the genre had an effect on the overall HR response was confounded by our inability to collect both rehearsal and performance data in all genres. However, we found that the physiological stress responses evoked were significantly altered by genre. Specifically, contemporary Christian musicians had significantly lower %MHR responses during rehearsals when compared to classic rock musicians during rehearsal and to metal rock and western musicians during performance. The generally overall reduced HR in the contemporary Christian musicians was probably due to three factors: 1) their performances and rehearsals were in the same venue; 2) the tempo of their songs was the lowest of all genres (Table 2); and 3) their rehearsal and performance durations were much shorter than the other genres.

Collectively, the music-induced elevated HR responses observed in this and other studies[2,13–15,18] and the fact that these HR responses fall into the moderate and vigorous ranges for physical training[5] raise questions about whether there are physiological benefits that arise through regular music playing. To our knowledge, the only existing study that has addressed this hypothesis was by Burgurrf et al.[20] In that study, subjects were matched by age, weight, activity levels, and a variety of other demographic data, but one group was composed of music students who played their instrument an average of 1.8 hrs/day more than the control group. Burgurrf and colleagues observed that in these music students, resting systolic, diastolic, and mean blood pressures were significantly lower than those in the control students. These observations led the authors to suggest that playing music produced beneficial cardiovascular effects.[20] We would further hypothesize that because of the elevated HR of musicians during performance, and the length of time that most musicians perform, this exposure would result in cardioprotection in these musicians. In contrast, the elevated HR responses evoked during musical performance also suggest the potential for health risks, particularly cardiovascular-related implications, for the professional musician who is in poor physical condition.[21,22]

In this investigation, some limitations may have restricted the generality of our findings to all upright musical performances. As a field study, there were conditions, such as temperature and humidity variation in the indoor and outdoor venues, that limit our conclusions. For instance, the contemporary Christian musicians rehearsed and performed in the same venue which was relatively cool and air-conditioned (72°). Conversely, other genres we analyzed routinely performed in different and unfamiliar environmental settings which varied markedly, such as being outdoors in hot/humid conditions (i.e., 87°, 67% humidity). However, while environmental conditions are well established to influence physiological responses and should be considered in all rehearsal/performance situations, we observed no association between venue temperature and humidity with the HR responses we measured.

TABLE 3. Multiple Regression Analysis of the Initiators of the %MHR

Independent Variable	B	β	t	p
BMI	1.284	0.531	4.063	**0.001***
Tempo	0.323	0.493	2.295	**0.031***
Event type	6.602	0.236	1.797	0.085
Years playing	0.202	0.201	1.465	0.156
Instrument type	1.219	0.240	1.927	0.066
Genre	0.389	0.029	0.147	0.888
Exercise participation	4.104	0.142	1.087	0.288
Venue temperature	0.158	0.177	0.880	0.389

B, unstandardized coefficient; β, standardized coefficient; t, t-statistic. Significance level set at p<0.05.*

$\hat{y}$ (predicted %MHR) = –28.167 + 1.284 (x_1) + 0.323 (x_2) + 1.219 (x_3), where x_1 = BMI, x_2= tempo, x_3= instrument type. r^2=0.506.

In summary, we observed that playing music, regardless of genre type, evoked significantly elevated HR responses during both rehearsal and public performances in professional musicians. Even with markedly increased HR responses within each genre and performance type, our data indicated that the genre type had an effect on the extent of the HR response during musical performance. Contemporary Christian musicians exhibited the lowest physiological stress response compared to classic rock musicians during public performance and metal rock musicians during rehearsal. The degree of the physiological stress responses, as represented by %MHR, was significantly attributed to BMI, tempo, and, to a lesser extent, instrument type. Currently, music playing is not considered a strenuous physical effort and thus not included as part of any known assessment within fitness or clinical rehabilitative facilities for health-risk stratification purposes. Though no epidemiological research has explored cardiovascular health among professional musicians, we suggest further investigations should determine if music playing has the potential to induce similar cardiovascular benefits of exercise, specifically cardioprotection.

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APPENDIX 1. HR Data for Musicians Excluded from Analysis

	Average HR (%MHR)		Peak HR Achieved (%MHR)	
	Rehearsal	Public Performance	Rehearsal	Public Performance
Keyboardist (classic rock)	121±4 (70%)	123±5 (75%)	135 (78%)	138 (80%)
Drummer (metal rock)	148±13 (75%)	190±7 (98%)	177 (91%)	202 (104%)

Data given as mean ± SD.