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Investigating the physiological demands of musical performance

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An understanding of the physiological demands of music performance can be used to inform musicians' training and help prevent performance-related health problems. While the psychology of performance has been relatively well researched, little is known about the physiological demands of music performance and the relevance of fitness to musicians. This study examined the oxygen uptake during performances of a series of pieces given by skilled pianists. Five undergraduate and postgraduate piano performance students were recruited at Trinity Laban Conservatoire of Music and Dance to give informal performances totaling approximately 20 minutes. Energy expenditure while playing was assessed via measurements of heart rate (HR) and oxygen uptake. Mean oxygen uptake was 8.65 ml.kg.min while certain pieces peaked around 25.00 ml.kg.min. Mean HR was 108.95 beats per minute (bpm) with certain pieces peaking at 173 bpm. Energy expenditure in piano playing appears to be intermittent in nature, with fluctuations in intensity within each piece and differences in intensity between pieces. From this study, it appears that mean oxygen uptake during piano playing is similar to that during brisk walking.

Keywords: energy expenditure; performance; pianists; indirect calorimetry; fitness

While the psychology of music performance has been extensively investigated, less is known concerning the physical demands—in particular, energy requirements. Llobet and Odam (2007) advocate the development of the musical "athlete", but what sort of athlete do musicians need to be? Research has

shown rock drumming to be an intense and physically demanding activity, with mean heart rate (HR) values of 155 bpm and peak HR values reaching 179 bpm, well in excess of age predicted maximum. This indicates that rock drumming is a high intensity activity, relying upon both the aerobic and anaerobic energy systems (Smith *et al.* 2008). Differences in heart rates have been identified between music practice and performance, and between different pieces of music, indicating that there is much variance in music playing with regard to energy requirements (Iñesta *et al.* 2008, Mulcahy *et al.* 1990). However, methods adopted by previous researchers to measure energy expenditure should be viewed with some caution. The use of heart rate as a means of predicting energy expenditure has been found to be unreliable during non-steady-state activities such as dance (Redding *et al.* 2004). Additionally, influential factors such as anxiety cast further doubt on the reliability of heart rate data. Indirect calorimetry through the measurement of oxygen consumption has been found to be the most reliable method for determining energy expenditure (McArdle *et al.* 2006).

The current study sought to develop a clearer understanding of the physiological demands of music performance and, in particular, the oxygen uptake during performance by skilled pianists.

METHOD

Participants

Participants were two undergraduate and three postgraduate piano performance students at Trinity Laban Conservatoire of Music and Dance (three male, two female, mean age=23.20 years, SD=3.27). Participation was restricted to pianists because it was important to observe one group of musicians at a time, and also because pianists can perform while wearing a portable gas analyzer mask.

Materials

Each participant was requested to prepare 20-30 minutes of music to a public performance standard. They were asked to choose pieces they perceived to be technically and physically demanding. A total of 13 pieces was recorded. Participants gave an informal solo performance, during which energy expenditure was assessed in two ways: a Polar heart rate monitor and watch (Polar Accurrex, USA) was used to monitor and record heart rate, and a portable telemetric gas analyser (Metamax 3*b*, Germany) measured oxygen uptake (VO_2).

Procedure

Necessary ethical clearance was obtained from the Trinity Laban Research Ethics Committee. Following the collection of informed consent from each participant, equipment for measurement was fitted. After becoming accustomed to playing with the equipment on, participants performed their first piece. The Metamax was then removed to allow the participant to drink water. Following calibration and reattachment, participants performed their second piece.

Data analysis

Ventilatory oxygen uptake (VO_2) data was calculated relative to each participant's body mass and described as milliliters per kg of body mass per min (ml.kg.min). This is to account for the varying body mass between participants, thus allowing for comparative analysis. Heart rate values were analyzed and expressed as beats per min (bpm) as well as calculated as percentages of each participant's age predicted HR maximum. Means and standard deviations as well as peak VO_2 and HR values were calculated for each piece of music.

RESULTS

The mean oxygen uptake for the 13 pieces was 8.65 ±2.55 ml.kg.min, with a range of 4.71-11.82 ml.kg.min. The mean % of HRmax was recorded as 55.43% of HRmax across the 13 pieces (mean 108.95 bpm; Table 1).

The 13 pieces of music differed considerably from each other in terms of duration, mean, and peak oxygen uptake. For example, Liszt's *Dante Sonata* lasted 18 minutes and reached a peak of 25 ml.kg.min, whilst Prokofiev's *Sonata No.7 (II)* lasted 6 minutes and reached a peak of 18 ml.kg.min (Figure 1). Furthermore, certain pieces fluctuated more in intensity than others. The data show a greater variation in intensity within Liszt's *Dante Sonata* than Chopin's *Barcarolle* for example (see Figure 1).

There was also a notable difference in heart rate between pieces. A mean HR of 157.40 bpm was recorded when Participant D performed Ligeti's *L'escalier du diable*, at one point rising to 173.00 bpm. The mean HR recorded while Participant B performed Ravel's *La Valse* was 90.86 bpm, lowering to 74.00 bpm at one point, which is consistent with a resting state.

In Ravel's *La Valse*, VO_2 peaked at 24.00 ml.kg.min, while in Chopin's *Barcorolle* it reached only 14.00 ml.kg.min at its maximum point (both Participant B). Chopin's *Barcorolle* was of overall lower intensity throughout,

Table 1. Duration, mean VO_2, mean HR, and mean %HR max for the performed pieces.

Pianist	*Piece*	*Duration (min)*	*Mean VO_2 (ml.kg.min)*	*Mean HR (bpm)*	*%HR max*
A	Liszt, Dante Sonata	18	8.37	118.59	61.13
A	Prokofiev, Sonata No. 7 (II)	6	6.69	106.61	54.95
A	Prokofiev, Sonata No. 7 (III)	4	9.88	125.15	64.51
B	Ravel, La Valse	12	11.36	90.86	45.89
B	Chopin, Barcarolle	9	8.21	76.56	38.67
C	Martinu, Cello Sonata No. 2 (I)	8	11.50	103.98	52.51
C	Ravel, Violin Sonata (II)	6	11.07	97.49	49.24
C	Ravel, Violin Sonata (III)	4	11.82	102.24	51.63
D	Liszt, Paganini Etude No. 2 in E*b*	7	9.04	137.61	71.30
D	Ligeti, L'escalier du diable	5	9.47	157.40	81.56
E	Debussy, Prelude No. 7	5	5.37	99.71	49.61
E	Chopin, Revolutionary Etude	4	4.92	99.54	49.52
E	Chopin, Ballade No. 4 in f	10	4.71	100.68	50.09
	Mean	7.54	8.65	108.95	55.43
	(±SD)	(4.01)	(2.55)	(21.11)	(11.48)

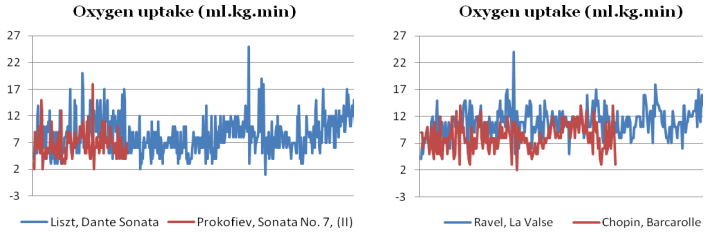

Figure 1. Oxygen uptake during two different pieces performed by Participant A (left panel) and Participant B (right panel). (See full color version at www.performance science.org.)

with a mean VO_2 of 8.21 ml.kg.min, compared with Ravel's *La Valse* which was performed at a mean VO_2 of 11.36 ml.kg.min (Figure 1, right panel).

DISCUSSION

The aim of this study was to investigate the physiological demands of music playing through a descriptive analysis of VO_2 and HR during the performing

of 13 piano pieces. The data show that the average VO_2 required to perform the piano pieces was 8.65 ±2.55 ml.kg.min. This is on par with activities such as brisk walking. While the overall mean oxygen uptake is relatively moderate, at certain times there are short high intensity bursts of activity which demand much more oxygen.

The mean HR recorded while Participant D performed Ligeti's *L'escalier du diable* was 157.40 bpm. This is similar to values previously recorded for rock drumming (Smith *et al.* 2008). It could be argued that certain pieces of piano music are performed at similar intensities to rock drumming therefore.

Findings show that there can be much variation between pieces. The mean VO_2 required to perform Chopin's *Ballads No. 4 in f* was 4.71 ml.kg.min, while the mean VO_2 required to perform Ravel's *Violin Sonata (III)* was 11.82 ml.kg.min. However, these two pieces were performed by two different participants. Factors such as the participants' activity-specific skill level could have affected how hard they needed to work to perform. Nevertheless, variation existed between pieces even when performed by the same participant (see Table1).

The data show that piano playing is an intermittent activity whereby intensities fluctuate in a non-steady fashion. This is consistent with findings in both Smith *et al.*'s (2008) rock drumming study and in the dance literature (e.g. Dahlstrom *et al.* 1996, Wyon *et al.* 2004). Implications are that consideration should be given to the training of musicians in terms of their cardiorespiratory fitness; supplementary physical training such as interval training could therefore form a valuable part of a musician's education.

For this initial study, it was decided to observe as many different pieces from different pianists as possible in order to gain a broad understanding of the energy requirements of piano performance. Future research could usefully examine the same piece played by a number of different participants to examine and account for possible differences in skill level. It should also be noted that variation may be caused by differences in participants' metabolisms due to gender, age, or body composition. Additionally, these findings cannot be applied to other instruments. Future research could examine the energy requirements of other instrumentalists and also vocal musicians to determine their physiological needs.

In conclusion, the present study demonstrates that physiological demands of different piano pieces vary and that piano playing is an intermittent activity. Overall, it appears to utilize the level of oxygen uptake needed to walk briskly, but can also peak at levels consistent with dance and rock drumming (Schantz and Astrand 1984, Smith *et al.* 2008).

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References

Dahlstrom M., Inasio J., Jansson E., and Kaijser L. (1996). Physical fitness and physical effort in dancers: A comparison of four major dance styles. *Impulse, 4,* pp. 193-209.

Iñesta C., Nicolás Terrados N., García D., and Pérez J. A. (2008). Heart rate in professional musicians. *Journal of Occupational Medicine and Toxicology, 3,* pp. 1-11.

Llobet J. R. and Odam G. (2007). *The Musician's Body*. Abingdon, UK: Ashgate.

McArdle W. D., Katch F. I., and Katch V. L. (2006). *Exercise Physiology* (6th ed.). Baltimore, Maryland, USA: Lippincott, Williams, and Williams.

Mulcahy D., Keegan J., Fingret A. *et al.* (1990). Circadian variation of heart rate is affected by environment: A study of continuous electrocardiographic monitoring in members of a symphony orchestra. *British Heart Journal, 64,* pp. 388-392.

Redding E., Wyon M., Shearman J., and Doggart L. (2004). Validity of using heart rate as a predictor of oxygen consumption in dance. *Journal of Dance Medicine and Science, 8,* pp. 69-72.

Smith M., Draper S., and Potter C. (2008). The energy cost of rock drumming: A case study. Paper presented at the *European College of Sport Science (ECSS) 13th Annual Congress,* Estoril, Portugal.

Schantz P. G. and Astrand P. O. (1984). Physiological characteristics of classical ballet. *Medicine and Science in Sport and Exercise, 16,* pp. 472-476.

Wyon M. A., Abt G., Redding E. *et al.* (2004). Oxygen uptake during modern dance class, rehearsal, and performance. *Journal of Strength and Conditioning Research, 18*, pp. 646-649.