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ORIGINAL ARTICLE – E-LEARNING

Neurocardiological differences between musicians and control subjects

J. L. I. Burggraaf · T. W. Elffers · F. M. Segeth · F. M. C. Austie · M. B. Plug · M. G. J. Gademan · A. C. Maan · S. Man · M. de Muynck · T. Soekkha · A. Simonsz · E. E. van der Wall · M. J. Schalij · C. A. Swenne

Abstract

Background Exercise training is beneficial in health and disease. Part of the training effect materialises in the brainstem due to the exercise-associated somatosensory nerve traffic. Because active music making also involves somatosensory nerve traffic, we hypothesised that this will have training effects resembling those of physical exercise.

Methods We compared two groups of healthy, young subjects between 18 and 30 years: 25 music students (13/12 male/female, group M) and 28 controls (12/16 male/female, group C), peers, who were non-musicians. Measurement sessions to determine resting heart rate, resting blood pressure and baroreflex sensitivity (BRS) were held during morning hours.

Results Groups M and C did not differ significantly in age (21.4±3.0 vs 21.2±3.1 years), height (1.79±0.11 vs 1.77±0.10 m), weight (68.0±9.1 vs 66.8±10.4 kg), body mass index (21.2±2.5 vs 21.3±2.4 kg m^{-2}) and physical exercise volume (39.3±38.8 vs 36.6±23.6 metabolic equivalent hours/week). Group M practised music daily for 1.8±0.7 h. In group M heart rate (65.1±10.6 vs 68.8±8.3 beats/min, trend P =0.08), systolic blood pressure (114.2±8.7 vs 120.3±10.0 mmHg, P=0.01), diastolic blood pressure (65.0±6.1 vs 71.0±6.2 mmHg, P<0.01) and mean blood pressure (83.7±6.4 vs 89.4±7.1, P<0.01) were lower than in group C. BRS in groups M and C was 12.9±6.7 and 11.3±5.8 ms/mmHg, respectively (P=0.17).

Conclusions The results of our study suggest that active music making has training effects resembling those of physical exercise training. Our study opens a new perspective, in which active music making, additionally to being an artistic activity, renders concrete health benefits for the musician.

Keywords Exercise training · Music · Heart rate · Blood pressure · Baroreflex

Introduction

Under resting conditions in healthy persons, the autonomic nervous system shows predominantly parasympathetic activity, while sympathetic outflow and the activity of the renin-angiotensin-aldosterone system are low. Neurohumoral activation (sympathoexcitation and excitation of the renin-angiotensin-aldosterone system in resting conditions) and a decrease in baroreflex sensitivity (BRS) play a key role in the genesis and progression of various major diseases such as diabetes [1, 2], metabolic syndrome [3, 4] and heart failure [5–8]. The therapeutic spectrum for these diseases is diverse, pharmacotherapy being a cornerstone, but lifestyle changes including regular physical exercise considerably improve prognosis and partly revert the abnormal resting conditions of neurohumoral activation and decreased BRS, for example as in heart failure [9].

Part of the effects of exercise training (i.e., changes in resting conditions that occur after one or multiple training

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J. L. I. Burggraaf · T. W. Elffers · F. M. Segeth · F. M. C. Austie · M. B. Plug · A. C. Maan · S. Man · E. E. van der Wall · M. J. Schalij · C. A. Swenne (✉)
Department of Cardiology, Leiden University Medical Center,
Albinusdreef 2, PO Box 9600, 2300 RC Leiden, the Netherlands
e-mail: c.a.swenne@lumc.nl

M. G. J. Gademan
Department of Public Health, Academic Medical Centre,
Amsterdam, the Netherlands

M. de Muynck · T. Soekkha
Academy for Creative and Performing Arts, Faculty of
Humanities, Leiden University, Leiden, the Netherlands

A. Simonsz
Pre-university College, Leiden University, Leiden, the Netherlands

sessions) materialise in the form of neural plasticity in the brainstem [10, 11]: in the nucleus tractus solitarii and in the caudal and rostral ventrolateral medulla, onto which somatosensory afferents project, from where sympathetic efferents originate, and where central baroreflex processing takes place. These effects in the central nervous system are most likely induced during training sessions by the exercise-inherent somatosensory nerve traffic: evidence for this hypothesis can be found in several studies about the effects of periodic electrical somatosensory stimulation (hence, without any actual exercise), often of the peroneal or sciatic nerve, often in a 2-per-second rhythm (actually: marching pace). Indeed, the observed effects parallel strikingly those of exercise: activation of the hypothalamic-endorphinergic system that exerts a direct inhibiting action on sympathetic outflow [12, 13]; generalised peripheral vasodilation [14]; reduction of plasma renin activity [15], reduction of plasma endothelin-1 levels [16, 17], increased bioavailability of nitric oxide [18], blood pressure reduction [19] and increased BRS [20, 21].

Extrapolating these findings, it is conceivable that forms of physical activity other than exercise-based activities exist which beneficially modulate the autonomic nervous system properties because of the activity-inherent somatosensory neural input to the brainstem. It is important to further investigate such potentially therapeutic activities because our society is adopting an increasingly sedentary lifestyle. Moreover, patients often have a reduced exercise tolerance that may severely limit their exercise training options. As active music making necessarily involves periodic/rhythmic somatosensory nerve activity, we hypothesised that some basic resting conditions that are under the influence of the autonomic nervous system (heart rate, blood pressure, BRS) would be lower (heart rate and blood pressure) or higher (BRS) in musicians than in non-musicians. We addressed this hypothesis in a pilot study with a transversal design, comparing a group of healthy young musicians with a group of control persons with comparable characteristics (sex, age, height, weight, body mass index, and weekly amount of physical activity).

Methods

The local Medical Ethics Committee approved the study protocol, and all studied subjects gave written informed consent to participate in the study.

Inclusion of subjects

Eligible participants were healthy males and females between 18 and 30 years old, using no medication with neural or cardiovascular effects. Two groups were formed. Group M (musicians) were subjects who practised music for at least 1 h per day. They were mainly recruited among a group of Leiden University students doing a minor in music at the Royal Conservatory in The Hague (Practicum Musicae program). Group C (control subjects) were mainly recruited among fellow students of the group M subjects.

To assess the amount of physical activity, each participant completed a questionnaire based on the Compendium of Physical Activities [22], encompassing regular walking and cycling habits as personal means of transport, as well as various training and sports activities. All activities were quantified by duration and intensity and multiplied by the corresponding amount of METs (metabolic equivalent of task) listed in the Compendium. Thus, the exercise volume (amount of MET·hours per week) was computed for every subject.

In addition, the study participants completed a lifestyle questionnaire to assess sleeping and smoking habits and alcohol and caffeine use.

Measurements

Measurement sessions were done in the morning [23] in a quiet room in the Leiden University Medical Center. Room temperature was kept at 23 °C. On the day preceding the measurements M subjects rehearsed normally, but all participating subjects abstained from sports activities and limited the number of alcoholic drinks to a maximum of two. On the day of the measurement, the subjects took their regular breakfast but abstained from caffeine-containing beverages (including energy drinks). Also, they did not exercise and took care not to rush during their travel to our hospital.

The measurement protocol greatly resembled that of one of our previous studies [24]. During the measurements, the subjects were in the supine horizontal position. First, a diagnostic ECG was taken to make sure that all subjects had a normal electrocardiogram. Then, the finger-cuff of a continuous noninvasive arterial blood pressure measurement device (Finometer; Finapres Medical Systems, Amsterdam, the Netherlands) was attached around the second phalanx of the left middle finger. The arm cuff of an automatic sphygmometer (Accutorr 3, Datascope, Montvale, NJ) was attached around the right upper arm. A standard 12-lead ECG was derived. The continuous noninvasive arterial blood pressure signal and the eight independent leads I, II, V1-V6 of the standard 12-lead ECG were recorded with a modified ST Surveyor monitoring system (Mortara Rangoni Europe, Casalecchio di Reno, BO, Italy) with a 500-Hz sampling rate.

After the subject had been supine for at least 15 min, and after making sure that the Finapres signal was stable (>50 beats between successive physio-calibrations), five consecutive Accutorr blood pressure and heart rate measurements were done at 2.5-min intervals. After removal of the highest and lowest measurements, the averages of the remaining three measurements were taken as the resting heart rate and blood pressure of that particular subject. Then, after

Table 1 Characteristics of the complete study group

	Group M	Group C	*P* value
N (male/female)	25 (13/12)	28 (12/16)	0.51 (NS)
Age (years)	21.4±3.0	21.2±3.1	0.40 (NS)
Height (m)	1.79±0.11	1.77±0.10	0.21 (NS)
Weight (kg)	68.0±9.1	66.8±10.4	0.33 (NS)
BMI ($kg \cdot m^{-2}$)	21.2±2.5	21.3±2.4	0.45 (NS)
Training (MET·h/wk)	39.3±38.8	36.6±23.6	0.38 (NS)
Sleep (h/day)	7.76±0.93	7.73±0.77	0.45 (NS)
Alcohol (drinks/day)	0.88±0.92	0.68±1.19	0.26 (NS)
Caffeine (drinks/day)	1.69±1.33	1.71±1.42	0.48 (NS)
Smoking (cigarettes/day)	0.05±0.22	0.88±3.25	0.13 (NS)

Demographic and anthropomorphic characteristics and lifestyle habits of the complete study group. There were no statistically significant differences between the M and the C groups. *M* musicians group; *C* control group; *BMI* body mass index; *MET* metabolic equivalent of task; *NS* non-significant ($P>0.05$)

having assured that the Finapres finger blood pressure values did not differ more than 10 mmHg from the Accutorr blood pressure values, and after the subject had been in the supine horizontal position for about 30 min, the Finapres Physiocal option was switched off, and the ECG and the non-invasive continuous arterial blood pressure signal were recorded for 10 min for later BRS calculation. During this period, the subjects performed 0.25 Hz metronome respiration, thus preventing the direct mechanical component of respiration and the respiratory gating effect from entering the low-frequency band (0.04–0.15 Hz), in which we compute BRS [25].

Analysis

BRS calculations were done over the complete 10-min blood pressure and ECG recording. In case of perturbation of these signals by, e.g., coughing, which was entered in our log computer during the recording, such a nonstationarity was cut out of the recording and BRS was calculated in two briefer periods. The BRS algorithm computes the magnitude of the transfer function between the systolic blood pressure variability (baroreflex input) and the interbeat interval (IBI) variability (output), averaged over the 0.04-to 0.15-Hz band. Additionally, it calculates 95 % two-sided BRS confidence intervals (CI) [26]. When more than one data episode had been defined within the 10-min measurement period, the overall BRS was composed from all the BRS and CI values in data segments by the best linear unbiased estimator (BLUE) method [27].

Statistics

Data are expressed as mean ± standard deviation (SD). A chi-square test (for the sex ratios) and Student's *t*-tests (for the continuous variables) at the 5 % significance level were used to find differences between the M and the C groups.

Results

Group characteristics

During the measurement sessions, it appeared that a number of subjects had to be excluded because of sinus bradycardia (heart rate <50 beats/min, 2 subjects) or wandering pacemaker (1 subject), because normal sinus rhythm is required for BRS calculation. Also, 1 subject with elevated blood pressure was excluded (the systolic and diastolic blood pressures of all participants had to be <140 mmHg and <90 mmHg, respectively). The diagnostic ECG of one subject showed Wolff-Parkinson-White syndrome. As this finding does not have an impact on the outcome variables of this study, this subject was not excluded. The resulting study group comprised 25 M subjects and 28 C subjects. Table 1 lists the demographic and anthropomorphic characteristics of the groups, their physical training volume and their lifestyle characteristics. There were no significant differences between the groups.

Table 2 Measurements of complete study group

	Group M	Group C	*P* value
N (male/female)	25 (13/12)	28 (12/16)	0.51 (NS)
Heart rate (beats/min)	65.1±10.6	68.8±8.3	0.08 (NS)
Systolic blood pressure (mmHg)	114.2±8.7	120.3±10.0	0.01
Diastolic blood pressure (mmHg)	65.0±6.1	71.0±6.2	<0.01
Mean blood pressure (mmHg)	83.7±6.4	89.4±7.1	<0.01
Baroreflex sensitivity ($ms.mmHg^{-1}$)	12.9±6.7	11.3±5.8	0.17 (NS)

Resting heart rate, blood pressure and baroreflex sensitivity in the complete study group. *M* musicians group; *C* control group; *NS* non-significant ($P>0.05$)

Table 3 Characteristics of the study group, smokers excluded

	Group M	Group C	*P* value
N (male/female)	24 (13/11)	25 (11/14)	0.48 (NS)
Age (years)	21.3±3.0	21.0±2.9	0.38 (NS)
Height (m)	1.80±0.11	1.76±0.10	0.13 (NS)
Weight (kg)	68.2±9.3	66.2±10.4	0.25 (NS)
BMI ($kg \cdot m^{-2}$)	21.2±2.6	21.3±2.5	0.45 (NS)
Training (MET·h/wk)	40.3±39.3	36.9±23.6	0.35 (NS)
Sleep (h/day)	7.74±0.90	7.63±0.82	0.34 (NS)
Alcohol (drinks/day)	0.91±0.92	0.74±1.17	0.30 (NS)
Caffeine (drinks/day)	1.67±1.28	1.70±1.37	0.48 (NS)

Demographic and anthropomorphic characteristics and lifestyle habits of the study group without smokers. There were no statistically significant differences between the M and the C groups. *M* musicians group; *C* control group; *BMI* body mass index; *MET* metabolic equivalent of task; *NS* non-significant ($P>0.05$)

In the M group, 6 subjects practised the piano, 5 voice, 4 flute, 3 guitar, 2 accordion, 2 clarinet, 2 harpsichord, 2 violin, 1 oboe, 1 viola da gamba and 1 violoncello (the total number is larger than 25 because some students practised more than 1 instrument). The average music practising time of the M group participants was 1.8±0.7 h.

Although no statistically significant lifestyle differences existed between the M and the C groups, there is a trend towards a difference in smoking habits: the average amount of cigarettes smoked per day was 0.88 in the C group, while it was 0.05 in the M group ($P=0.13$). There were 3 smokers in the C group and 1 in the M group. We decided, hence, to also include results for the whole study group minus the smokers.

Resting heart rate, blood pressure, and baroreflex sensitivity

No technical problems occurred and all variables could be measured in all subjects. The results of the measurements have been summarised in Table 2. Blood pressure was significantly lower in the M group than in the C group, and there was a trend towards a lower heart rate in the M group. The average baroreflex sensitivity in the M group was larger than in the C group, but this difference did not reach statistical significance.

Statistical analysis of the non-smoking study participants

The results of the non-smoking subjects have been summarised in Tables 3 and 4. Basically, the results are similar to those of the complete study group, as described in the previous paragraph.

Discussion

Our pilot study, presented here, compared transversally some basic neurocardiological variables between a group of healthy young musicians and a matched group of non-musicians. We found (Table 2) that blood pressure in the musicians was lower than in the control subjects, heart rate tended to be lower, while the difference in BRS did not reach statistical significance. However, the musicians had the largest average BRS, and it is well possible that a larger group size would lead to significant differences in heart rate and in BRS as well. All measured differences between musicians and non-musicians, statistically significant or not, assumed the direction that was to be expected on the base of exercise-training-like effects: blood pressure was lower (significantly), heart rate was lower (statistical trend) and BRS was larger (but not significant) in the musicians group. The measurements in the complete study group and in the non-smoking participants yield quite similar results.

It is possible that a somewhat smaller, although not significantly different, proportion of females in the M group may have accentuated the BRS difference with the C group, as young adult females tend to have lower BRS values [28]. However, as young adult females tend to have lower blood pressures than males, the lower proportion of females in the M group rather reinforces the observation that M group blood pressures were significantly lower than C group blood pressures [28].

Up to now, the physiological effects of music on the body have been studied manifold. Invariably, such studies address the immediate, momentary, influences of music, either during passive listening [29–31] or during or immediately following

Table 4 Measurements with smokers excluded

	Group M	Group C	*P* value
N (male/female)	24 (13/11)	25 (11/14)	0.48 (NS)
Heart rate (beats/min)	65.5±10.7	68.4±8.4	0.14 (NS)
Systolic blood pressure (mmHg)	114.4±8.9	120.5±10.4	0.02
Diastolic blood pressure (mmHg)	64.9±6.2	71.1±5.9	<0.01
Mean blood pressure (mmHg)	83.8±6.6	89.5±7.3	<0.01
Baroreflex sensitivity ($ms.mmHg^{-1}$)	12.8±6.8	11.2±5.8	0.19 (NS)

Resting heart rate, blood pressure and baroreflex sensitivity in the study group without smokers. *M* musicians group; *C* control group; *NS* non-significant ($P>0.05$)

actual active music making [32–34]. To our knowledge, no studies exist that report long-term, training-like effects of active music making (an attempt to demonstrate superior lung function in wind instrument players and singers failed [35, 36]). Beneficial changes in resting conditions are very important, because in most persons, even in those who exercise regularly, the body is most of the day in rest. Hence, an important goal of exercise training for health purposes is to modify the resting condition of the trainee. On the basis of parallels with physical training, namely the presence of increased afferent somatosensory nerve traffic during exercise, we expected similar beneficial effects after active music making as following exercise, namely heart rate lowering [37], blood pressure lowering [38] and increased baroreflex gain [39]. The results of our study support this hypothesis, what renders active music making a potentially therapeutic or preventive activity that merits further study. The finding of a lower blood pressure in the M group may be particularly important because although the subjects we studied were young, blood pressure tracks into adulthood [40] and it has been demonstrated that blood pressure during young adulthood is associated with death from heart disease, cardiovascular disease, and all causes decades later [41, 42].

Limitations

As the demographic, anthropomorphic, lifestyle and exercising characteristics are very comparable in group M and C, it is likely that the observed differences between the M and the C group are to be explained by the active music making by group M. There might, however, be additional factors, e.g., a certain genetic predisposition, which might explain part of the observed differences. Basically, an intervention study in musicians with a crossover design would be needed to generate a definite proof of our observation.

It is conceivable that the training effect depends on the music instrument. E.g., playing a percussion instrument (though not in our study group) is likely to involve strong somatosensory neural traffic and might, therefore, constitute a relatively strong training stimulus. Our group size is too small to differentiate between the musical instruments involved.

We studied young healthy students; it is likely that similar effects will be found in older persons and possibly even diseased persons because of the parallels with physical exercise. It is pertinent for future studies to investigate the possible role of active music making in secondary prevention and in rehabilitation.

Conclusions

Our study suggests that active music making has some training effects that resemble those of physical exercise training, namely heart rate and blood pressure lowering and baroreflex reinforcement. Further studies should be done to corroborate these findings. Our study opens a new perspective, in which active music making, additionally to being an artistic activity, renders concrete health benefits for the musician (professional and non-professional).

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Conflicts of interest None.

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