EFFECTS OF TEMPO AND DRUMMING PATTERN UPON THE ENERGY COST AND GROUND REACTION FORCE OF JAPANESE DRUM PLAYING EXERCISE

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INTRODUCTION

Japanese drum playing exercise (JDPE), one of the most complex and highly developed skills, has recently become a popular art with an increasing number of professional players with concerts or events all over the world. Despite its current popularity and long history, little quantitative information exists as to the physiological responses to this unique type of exercise. On the other hand, several investigators have analyzed the physiological and biomechanical data in music instrumental playing (Bejjani & Halpern, 1989; Bouhuys, 1969). The unique nature of JDPE, in which the right and left stick arm movements alternate rapidly with bursts of dynamic activity, is of special interest. The assessment of varied tempo and drumming pattern may be important in predicting performance of JDPE. The duration of JDPE, which is about 5 to 7 min in concerts or events, may require the ability to combined arm and leg exercise at a high intensity for the playing time. It seems that an important element in drumming is the volume of oxygen consumed, and the force generated to the ground as the drummer attempts to beat the drum while performing certain musical tasks.

Therefore, the purpose of this study was to investigate effects of tempo and drumming pattern upon the energy cost and ground reaction force of JDPE.

METHODS

EXPERIMENTAL DESIGN

Virtuosi male Japanese drum players (N=7) participated in this study. Physical characteristics of subjects are presented in Table 1. The subjects was training as Japanese drum player. Each subject performed playing a large Japanese drum (Nagadoudaiko) with a pair of large wooden sticks (0.53 kg) at three tempos (90, 120, and 150 beats/min) by three drumming patterns (single sticking; S, "Futatsu-uchi"; F, "Mitsu-uchi"; M, Figure 1) so as to maintain a sound level (120 dB), and also performed 9 trials for 45 min (5 min x 9 trials). The sound level was measured using a digital sound level meter (NIHON IRYOKIKI NS-311), and was immediately displayed by a personal computer (NEC PC-9821Nm) to the subjects in order to keep a constant sound level. The order of all trials was randomized, and tempo and drumming pattern were synchronized with a metronome (NIPPON GAKKI YAMAHA P-33).

Table 1. Physical characteristics of subjects (Mead- SD)

		Virtuosi players (N=7)
Age	(yrs)	29.9k5.5
Height	(cm)	171.9 ± 4.3
Body Weight	(kg)	66.5 ± 12.5
VO2max	(l/min)	2.86 ± 0.5
	(ml/kg/min)	43.3 ± 3.6
HRmax	(beats/min)	189.1 ± 9.8

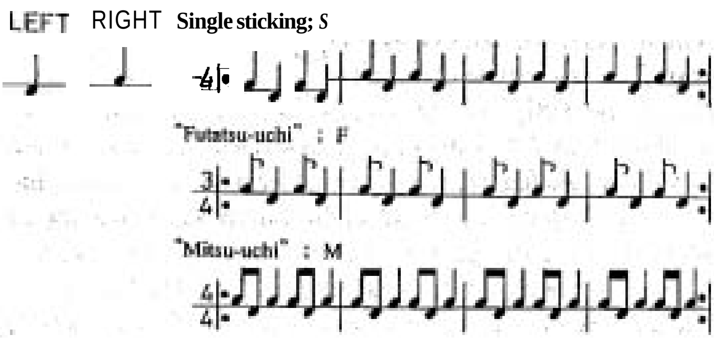

Figure 1. Drumming patterns used in this study

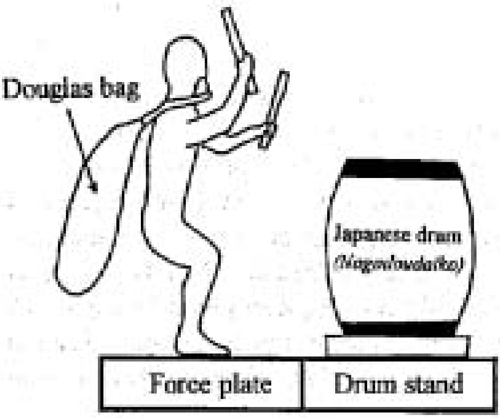

Figure 2. Schematic diagram of experiment

METABOLIC MEASUREMENTS

For all trials, Oxygen uptake (VO_2) were measured for last 1 min during 5 min playing. Heart rate (HR) was recorded by radio-telemetry (NIHON KOHDEN OEC-6201) during 5 min playing. Expired respiratory gas was collected using a Douglas bag. VO_2 was determined with Douglas bag technique. The expired gas was collected for last 1 min during 5 min playing (Figure 2). Gas volume was determined in a dry gas meter (SHINAGAWA SEIKI DC-5). Gas sample were analyzed according to the Scholander technique for O_2 and CO_2, respectively. An estimate of caloric cost was obtained by multiplying VO_2 (l/min) by 5.05, which represents the caloric equivalent of a respiratory exchange ratio of 1.0 (McArdle, Katch, & Katch, 1991). Ratings of perceived exertion (RPE) were determined immediately after each trial using the 15-point Borg scale (Borg, 1982). Maximal oxygen uptake (VO_2max) was determined using a Jonas body guard bicycle ergometer. In the VO_2max test, the subject pedaled at 60 rpm, and the work load was progressively increased until the subject was unable to continue. HR was recorded and the expired gas was collected in two Douglas bags during the last 2 min of the work period. The usual criterion of a plateau or decrease in VO_2 with an increase in work rate was used to indicate that the maximal value had been achieved. The order of testing at these maximal work rates was randomly assigned. At the beginning of testing the subject "warmed up" for 2 min at 1 kp. Each subject received auditory and visual pacing from a metronome.

GROUND REACTION FORCE RECORDINGS

In order to record three-components of force; vertical, anterior-posterior, and medio-lateral force, for 5 min, each player stood on a strain-gauge type force plate (TAKEI KIKI KOGYO, Figure 2). The basic parameters of ground reaction force for all trials during JDPE were defined as maximum vertical (F1), minimum vertical (F2), anterior peak (F3), posterior peak (F4), right peak (F5), and left peak (F6) forces.

STATISTICAL ANALYSIS

A two-way analysis of variance (ANOVA) with repeated measurements was used with "tempo" and "drumming pattern" as the main factors. The projected Least Significant Difference (LSD) was used to compare the means of the variables of each tempo and drumming pattern. Pearson product moment correlation coefficients were used to compare ground reaction force parameters and %HRmax, $\%VO_2max$ and RPE results. All comparisons were considered significant at $p<0.05$.

RESULTS

In metabolic measurements, ANOVA showed that for tempo and drumming pattern, no significant difference was observed in any physiological variables involving the energy cost. On the other hand, in ground reaction force recordings, ANOVA revealed that the maximum and minimum vertical (F1 and F2) and the anterior-posterior peak (F3 and F4) forces were significantly different among drumming patterns, and that F1 showed significant difference among tempos ($p<0.05$, Figure 3).

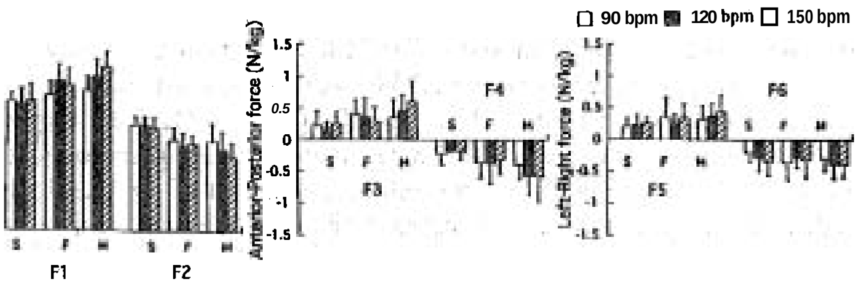

Figure 3. Ground reaction forces of each parameter for last 1 min. during 5 min. playing
(Mean ± SD of cycles, S:Single sticking; F:"Futatsu-uchi"; M:"Mitsu-uchi"

Correlation coefficient between all ground reaction force parameters and %HRmax showed significant difference ($p<0.05$, Table 2). Similarly, significant difference between parameters and %VO_2max, except for F3 and F5, was found ($p<0.05$). Moreover, significant difference between F5-F6 and RPE was found ($p<0.05$).

Variable	Ground reaction force parameters					
	Vertical		Anterior-Posterior		Medio-Lateral	
	F1	F2	F3	F4	F5	F6
%HRmax	0.404*	-0.448*	0.410'	-0.364'	0.424'	-0.478'
%VO_2max	0.564'	-0.466*	0.186	-0.302'	-0.035	-0.519'
RPE	0.159	-0.006	-0 128	0.017	-0.414'	0.392*

*: P<0.05

Table 2. Correlation coefficient between ground reaction force parameters and %HRmax, %VO_2max, and RPE during 5 min playing in virtuosi players

DISCUSSION

In this study, for tempo and drumming pattern, no significant difference was observed in any physiological variables involving the energy cost. The energy cost of various modes of exercise are shown in Table 3.

Exercise	Sex	N	Energy cost (kcal/min)	Energy cost (cal/kg/min)	References
Marching	male	12	5.90±0.91	·	Edholm, O G, Fletcher, J G.,
Running	auk	10	11.80±1.24	·	Widdowson, E M & McCance, R. A, 1995
Cycling	male	10	7.79±0.98	·	
Cross-country skiing	male, female	4	9 27±0.92	-	Christensen, E H & Hogberg, P., 1950
P i p skating	female	2	9.56	182 5	Gordon, T.I., Banister & Gordon, B. P, 1969
Aerobic dancing; Low	male, female	4	4.06±0.16	70±10	Igbanugo, V & Gutin, B., 1978
Medium	male, female	4	6 . 0 1	100±10	
High	male, female	4	8.19±0.99	140±20	
Disco dancing	male	7	11.60±3.60	-	Leger, L C., 1982
JDPE; S 90 bpm	male	7	3.55±1.09	55.2±2.2	Present study
120 bpm	male	7	4.37±1.74	70.4±196	
150 bpm	male	7	4.56±166	70.8±30.3	
F 90 bpm	male	7	4.60±1.71	70.6t17.6	
120 bpm	male	7	5.04±0.93	77.9±19.9	
150 bpm	male	7	4.71±1.07	7134136	
M 90 bpm	male	7	4.58±1.64	69.2±22.1	
120 bpm	male	7	4.97±1.29	76.0±10.1	
150 bpm	male	7	6.48±1.76	97.0±13.9	

JDPE: Japanese drum playing exercise S: Single striking F: "Futatsu-uchi" M: "Mitsu-uchi"

Table 3. Comparison of energy cost among vaiious modes of exercise

The value calculated in S at 120 and 150 bpm, F at 90,120, and 150 bpm, and M at 90,120 bpm were similar to the energy cost of low impact aerobic dancing. The value calculated in S at 90 bpm was lower than that of low impact aerobic dancing. In addition, the value calculated in M at 150 bpm was similar to the energy cost of medium impact aerobic dancing. Emphasis here may be made of the powerful component of JDPE. Empirically, it is well known that JDPE is a mixed type of exercise. Some movements are' primarily static while other movements are primarily more dynamic(arm movements). This powerful component is especially evident during fast tempo and drumming pattern in which the emphasis is on balance, muscular control, maintaining body placement, positioning of upper- and lower- body, and supporting the body weight. Thus, JDPE involves a dynamic component especially evident during fast tempo and drumming pattern.

In dynamic responses, maximum vertical ground reaction force showed significant difference among tempos ($p<0.05$), and also the difference of drumming patterns would have significant effect on the displacement of the body's center of gravity in both the vertical and the A-P directions (Figure 3).

As for correlation coefficient among ground reaction force parameters and %HRmax, %VO_2max, there was almost significant difference ($p<0.05$). The application of the results from this study to JDPE supports the need for upper- and lower- body involvement when JDPE. Therefore, it seemed that the dynamic responses have an influence on the physiological responses.

CONCLUSIONS

It was concluded that the energy cost and ground reaction force of JDPE resulted from not only arm work but also cyclic oscillations of center of mass of the body.

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