Bimanual skills and symmetry of upper limb movement in a group of drummers

Zdolności bimanualne i symetria ruchów kończyn górnych w grupie perkusistów

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Key words
Eye-hand coordination, bimanual coordination, drummers, laterализация

Abstract
Introduction: Hand-eye coordination is essential to carry out daily activities or take part in sports. Developing strong visual-motor coordination is especially important for athletes or musicians who rely on it for their careers.

Goal: This study aimed to evaluate visual-motor coordination in drummers’ upper limbs.

Materials and methods: The study group consisted of 60 men, aged 20 to 30 years (average 24.62 ±2.48). The respondents were divided into two groups, group P consisted of 30 experienced drummers and group N of 30 non-drummers. Standardized tests were employed: Relative Hand Skill test (RHS test) and a plate tapping test.

Results: The RHS test conducted on an original sample demonstrated no significant difference between the P and N group for the dominant limb (p=0.7272) or the non-dominant limb (p=0.3274). A significant difference was observed between the P and N group in the plate tapping test. The difference in the plate tapping test results between the dominant and non-dominant hands was significantly smaller in the P group than in the N group (p< 0.0001).

Stwierdzono istotną różnicę między grupą P a grupą N w teście koordynacji wzrokowo-ruchowej koordynacyjnej kośćmi górnych u osób grających na perkusji, niż u osób nie grających na perkusji. W grupie perkusistów zaobserwowano lepszą koordynację wzrokowo-ruchową kończyn górnych, niż u osób nie grających na perkusji. W grupie perkusistów koordynacja wzrokowo-ruchowa była istotnie mniejsza w grupie P niż w grupie N (p< 0.0001).

Wnioski: W grupie perkusistów zaobserwowano lepszą koordynację wzrokowo-ruchową kończyn górnych, niż u osób nie grających na perkusji w plate tapping test oraz istotnie mniejszą różnicę w zdolnościach koordynacyjnych kończyn górnej dominującej i niedominującej.
INTRODUCTION

Hand-eye coordination is essential in human life when performing daily activities or taking part in sport. Poor hand-eye coordination may impair our daily functioning and cause problems with gait, writing or even with eating. Developing strong visual-motor coordination is particularly important for athletes or musicians who rely on it for their careers. Through their regular training individuals can become highly coordinated in specific motor behaviour.

Experienced drummers, whose work can be compared with sports training, are able to perform highly organised and complicated manual activities thanks to stable and controlled, agile limb movements.1

Most common daily movements require a certain level of cooperation between the limbs. As a result of cultural pressure, the complexity of human bimanual skills has increased. Bimanual movements are characterised by considerable adaptation and dependency on context. Some tasks require actions activating both limbs, while others require more varied roles for each hand, e.g. playing musical instruments or sports training. This indicates a high level of modularity in controlling bimanual movements.2,3

Spatiotemporal relations between eye and hand movements are complex in natural human behaviors4,5,6, but are probably best understood in terms of vision optimisation for controlling the movement of the hand.7,8,9 Time coupling of eye and hand movements changes depending on the task, presumably in order to optimise the useful flow of visual information for the specific task.10

When considering eye-hand coordination, we must also pay attention to control of the hand. During intentionality activity, the hand not only heads for the right position but also adjusts its shape in anticipation of the size and orientation of the target, long before making contact. An effective grasp requires coding of the object’s spatial location and intrinsic properties (size and shape) and the transformation of these properties into a pattern of discrete movements (finger and wrist). Although the parietal cortex has long been considered a high-order sensory area, specialising in spatial awareness and action management, its role in processing three-dimensional shape for grasping is now becoming clearer. The anterior intraparietal cortex (AIP) includes neurons that encode the size, shape and orientation of grasped objects. These functions help to access the position of the hand and fingers during the action of grasping. AIP manages the visual control of hand movement, especially when matching the movement pattern with the spatial features of the object which is to be manipulated.11

Improved eye-hand coordination can be characterised not only by a shorter duration of action, but also a relatively longer timefixating the eyes upon an object before its arrival, which may be facilitated by a longer period between the eyes departing an object and its release by the hand.

This feature of better eye-hand coordination is inconsistent with better bimanual coordination, defined as a shorter interval between the work of the hands. This discrepancy can be attributed to the fact that the serial relationship between the eye and the hand differs from the parallel relationship of both hands. In eye-hand coordination, visual information from the eyes is transformed into hand movements in serial order, however in bilateral coordination both hands are managed as one unit and processed almost simultaneously.12,13

AIM OF THE STUDY

This study aimed to evaluate the skill of eye-hand coordination in the upper limbs of drummers and in a control group. The following research questions were asked:
• What is the level of eye-hand coordination in the group of drummers and in the control group?
• Are there differences in the coordination abilities of dominant and non-dominant upper limb in the group of drummers and in the control group?

MATERIALS AND METHOD

Characteristics of the study group

The study group consisted of 60 men aged between 20 and 30 years (average 24.62 years ±2.48). The subjects were divided into two groups, group P consisted of 30 male drummers and group N of 30 male non-drummers. All participants declared their right hand as the dominant hand. All the drummers actively practised and played the instrument. Average experience in playing drums was 8.17 years ±2.85, of which the shortest playing time is 5 years, and the longest 15 years.

Criteria for inclusion:
• no traumatic upper limbs injury,
• no upper limbs pain coming from lesions and its overload,
• no sight or hearing defects,
• declared full functional efficiency of the upper limbs,
• actively playing the drums for at least 5 years with a training duration not less than 5 hours/week (for group P),
• informed consent to participate in the study.

STUDY METHODOLOGY

The study was conducted between March and May 2019. Before starting the study, a questionnaire was completed by each of the participants to gather the following data: age, declared dominant hand, occupation, hobbies and history of traumatic injuries and other health problems (musculoskeletal, circulatory and nervous system) of upper limbs, in order to exclude their potential impact on the test results. The questionnaire also captured how long the participants had been playing the drums and the frequency and nature of their drum practise habits.

The study involved the performance of two standardised tests: the Relative Hand Skill (RHS test) and the Plate tapping test. RHS was used to confirm dominant hand and also for a preliminary assessment of the coordination abilities of both limbs. The test uses a series of circles arranged in
a repeating pattern. The participant of the study is asked to place a dot in each of the circles. The test consists of four attempts, 20 seconds long each, with two attempts performed by each hand. The final result is given by calculating the difference between the total results for the left limb (L) and the right limb (R), and then dividing it by the sum of two results of right-left and right+left. Results closer to zero indicate similar coordination abilities of both limbs.14

The Plate Tapping test (PLT) evaluates the speed of hand movements. To perform the test, a horizontal worktop with two discs of a certain size is necessary. The exerciser’s task is to move the tested limb as fast as possible from one disc to another over the second hand which must be kept on the worktop between the two discs. The time is counted from the starting moment until the participant performs 25 cycles, which is 50 movements (1 cycle means touching both discs). The test is performed twice for each of the limbs.15

Before proceeding with the study, all participants were informed that their anonymity would be maintained in accordance with the General Data Protection Regulation, implemented on May 10, 2018 (Polish Journal of Laws of 2018, item 1781). The study was planned and conducted in accordance with the Helsinki Declaration. All the participants were informed of all the procedures and gave informed consent to participate.

**Statistical analysis**

To develop the research findings descriptive statistics and statistical tests were used: T–test for independent samples. The significance level of $p < 0.05$ was adopted.

**STUDY RESULTS**

In the RHS test, group P attained a lower result than group N, respectively 28.54 and 30.8. This means that in group P a more similar level of coordination of dominant and non-dominant limb was observed than in group N. The test also confirmed the declared dominance of the right hand; none of the participants obtained a negative result.

The P group obtained a slightly higher number of markings in the RHS test than the N group. The average of the two tests for the dominant limb was, respectively, 89 in the P group and 88 in the N group. The difference was slightly higher in the case of non-dominant limbs; people in the P group marked correctly on average 49.8, and in the N group 47.5 circles.

A t-test for independent samples found no significant difference in the RHS test between the P and the N group for either the dominant limb ($p=0.7272$) or non-dominant one ($p=0.3274$).

A significant difference in upper limb coordination was seen in the Plate Tapping test. The average performance time from 2 attempts was 10.3s in the P group and 12.73s in the N group. For the dominant limb, the average time of performing the test was 9.78s in the P group and 11.21s in the N group, and for the non-dominant limb respectively 10.82s and 14.26s. A t-test for independent samples showed a significant difference in the result of Plate Tapping test between the dominant limb and non-dominant one, both in the P and N group. The result for the dominant limb was significantly shorter than for the non-dominant limb in the P group ($p=0.0007$) and in the N group $N (p < 0.0001)$.

The average difference between the right and left limb in the first trial was 0.97s in the P group and 2.86s in the N group, the difference being 1.89s. In the second trial, the difference in speed of the dominant and non-dominant limb in the P group was 1.12s and in the N group 3.23s, the difference being 2.11s. Based on the two trials, the average difference between the dominant and non-dominant limb was 1.04s in the P group

![Figure 1](image_url)

**Table 1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average</th>
<th>SD</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
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<td>Dominant limb</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Group P</td>
<td>89.0</td>
<td>11.8</td>
<td>0.3505</td>
<td>0.7272</td>
</tr>
<tr>
<td>Group N</td>
<td>88.0</td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-dominant limb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group P</td>
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<td>9.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group N</td>
<td>47.5</td>
<td>8.4</td>
<td>0.9878</td>
<td>0.3274</td>
</tr>
</tbody>
</table>

The average difference in time of performing the Plate Tapping test based on two trials
and 3.05s in the N group, with a difference of 2.01s between the two groups.

A t-test for independent samples found a significant difference between the P and N group. The difference in the Plate Tapping test between the dominant and non-dominant limb was significantly smaller in the P group than in the N group ($p < 0.0001$).

### DISCUSSION

We subconsciously use eye-hand coordination while performing many physical activities such as reaching for specific objects, grabbing, writing or practising various sport disciplines. Good eye-hand coordination is particularly important for people who use their coordination skills professionally, such as athletes or musicians, for whom achieving the maximum potential of their motor skills is critical to their success. Many daily movements rely on the bimanual skills required for coordination between the hands. Poor coordination capabilities may impair proper functioning and cause problems with walking, writing or eating meals.

In research by Fuji at al. it was shown that experienced drummers have a reduced difference in the maximum frequency of hitting between the right and left hand, together with highly stable efficiency when fast bimanual coordination is needed. Another study investigating asymmetry in the speed of hitting drumsticks onto the acoustic surface of drums found no significant difference in the right hand hitting speed of the drummers and the control group. However, the drummers demonstrated lower asymmetry in speed between the left and right hand. The authors of this paper suggest that hitting speed of the non-dominant hand has almost reached the level the dominant hand thanks to daily drum practising. The results of our own research are consistent with these conclusions.

In the Plate Tapping test for dominant and non-dominant hand, the drummers obtained shorter times than those who do not play this instrument. The difference in speed of performing the Plate Tapping was considerable and statistically significant. Furthermore, the difference between dominant and non-dominant hand was significantly lower among the drummers than non-drummers. Jäncke at al. used the indicator - index finger tapping task – TAP to evaluate hand asymmetry. They found better results for the right hand and a lower degree of asymmetry in the musicians’ manual skills than in non-musicians. Musicians who play mainly on stringed instruments, without any difference as regards the asymmetry of hand skills. Reduced asymmetry in the TAP test in musicians was related to an early start and experience in playing the instrument. The results of our own research accord with the authors’ conclusions in these publications.

Eye-hand coordination uses the eyes to direct attention to the hands in order to perform a certain task. The majority of upper limb movements require effective visual guidance. Eye-hand coordination and grip strength become necessary for effective performance in daily activities, practise in various sport disciplines and at work. Good eye-hand coordination involves the synergistic function of several sensory-motor systems, including the visual system, the vestibular system, proprioception and eye, head and shoulder systems, as well as aspects of cognitive attention and memory. However, eye-hand coordination also evokes combinatorial problems which do not arise when testing individual component systems of coordination in isolation. Remembering this basic fact is our best tool in understanding the function of the whole system.

Fujii at al. analysed the synchronization of beats into a drum set with an aural metronome. The study was conducted in a group of 15 professional drummers. In consecutive tests they used the metronome settings of 60, 120 and 200 beats per minute (BPM). In conditions of 60 and 120 BPM, the right hand showed a small delay relative to the metronome (~2ms), while the left hand and the right foot outran the metronome by approximately 10ms. In conditions of 200 BPM, the right hand was delayed by approximately 10ms in relation to the metronome, while the left hand and the right foot showed a slight delay (~1ms). These results may suggest that each limb was synchronised with different limbs depending on the speed of the metronome.

When investigating eye-hand coordination we should also consider the role of the hand itself. During intentional movement the hand not only...
moves to towards the right position but also adjusts its shape in anticipation of the target size and orientation long before making the contact. Effective grasping requires coding of the spatial location of the object and its intrinsic properties (size and shape) and transformation of these properties into a pattern of distal movements (finger and wrist). Although the parietal cortex has long been considered as a high-order sensory area specialising in spatial awareness and action management, its role in processing three-dimensional shapes onto grasping activity (ability) is now becoming clearer.21

Eriksen at al.23 examined the influence of mechanical limitation of the shoulder joints on the frequency of drum beats in two groups of participants; drummers and non-drummers. Consecutive tests were performed with different conditions under which the arm joints were constrained. In the first attempt it was permitted to use all three joints (shoulder, elbow, wrist). In subsequent attempts, movement was mechanically limited such that participants were allowed use of only the shoulder or wrist joint. Each condition was tested bimanually, and unimanually with both left and right hand. In each test, the participants performed the task of hitting a drumstick onto a percussion pad as frequently as possible within a specified time (15 s). The drummers achieved much higher average hitting frequencies in comparison with non-drummers. The results suggest that the drummers acquire sophisticated patterns of joints coordination of upper limbs, particularly in the arm’s more distal joints, in comparison to non-drummers.

In the effective coordination of bimanual movements, information must be exchanged between the hemispheres of the brain. The main structure of communication between the hemispheres of the brain is the corpus callosum (CC), which allows the interhemispheric integration of motor, sensory and cognitive processes. The myelin sheath surrounding the CC fibres enables quick and synchronised transfer of information.24,25 CC myelination is not only conducive to quick and synchronised information transfer, but can also increase inter-hemispheric inhibition of mirror movements. During physical development, mirror movements decrease in frequency and intensity. At around the age of ten we can observe a sudden drop in activity of these movements, possibly as a result of CC myelination.26 Since both hands often have to perform various movements simultaneously during daily activities, the increased inhibition of mirror movements with age leads to improvement in bimanual coordination and therefore an improvement in task performance.27 Patston at al.28 used an electroencephalogram test in a group of right-handed musicians and a control group of non-musicians. The results suggest that musicians have more bilateral neuronal connections than non-musicians, born out in their remarkable lack of asymmetry. The authors believe that plastic developmental changes caused by advanced musical training during childhood lead to comparably efficient connections to both brain hemispheres. Reaction speed and reduced asymmetry between the limbs may be associated with reduced time of inter-hemispheric transfer. While our research results were obtained without use of specialised medical tools such as electroencephalography (EEG) or electromyography (EMG) they indicate similar coordination skills among the group of drummers. Our results were obtained with the use of a standardised test RHS. It would be beneficial for future investigations to extend the research tools and/or use of other medical devices.

Eye-hand coordination is the ability of our brain to coordinate the information received by our eyes in order to control and manage our hand movements to perform a specific task. Eye-hand coordination utilises the eyes to direct attention to the hands to perform a particular task. Most upper limb movements typical of daily activities require effective visual guidance. Eye-hand coordination and grip strength become indispensable in the effective performance of daily activities. Impairment of this coordination as a result of stroke, traumatic injuries or developmental disorders may lead to significant deterioration of performance and quality of life.11

Music therapy can become an effective form of support for physiotherapy based on stimulation of the central nervous system (Polish, Centralny Uklad Nerwowy (CUN)), improving limb movement. Activities related to playing percussive instruments can be used to treat and prevent the loss of coordinating functions during the course of various diseases.29

Musical training is often used in the rehabilitation of people who underwent a stroke. Schneider at al.30 in their research used an electronic drum set for motor coordination training of the shoulders, and a piano for accurate motor control training of the hands and fingers in patients after a stroke. In comparison with the control group given only conventional treatment, patients from the musical group showed better movement control when performing the tests. Significantly, those tests were not associated with music, indicating the transference of the acquired motor skills to everyday activities. Bukowska at al.31 studied the influence of musical training on a course of treatment for Parkinson’s disease (PD). The inclusion criteria included stage 2 or 3 PD according to Hoehn and Yahr, the ability to walk independently and stable pharmacological treatment throughout the duration of the study. Their research employed all three techniques of Neurologic Music Therapy (NMT): Rhythmic Auditory Stimulation (RAS), Patterned Sensory Enhance (PSE) and Therapeutic Instrument Music Performance (TIMP). They found that combining all three NMT techniques can be used to improve gait and other rhythmic activities in the rehabilitation of patients with PD. Their results showed a significant improvement in the majority of spatiotemporal gait parameters and the authors suggest a new strategy for compensating movement and posture control by employing music and sound.

Since music is an integral part of life for many of us, it is worth using it not only for improving our coor-
CONCLUSIONS

- For drummers, the level of eye-hand coordination of upper limbs is visibly better in comparison with non-drummers.

- The drummers are characterised by significantly smaller difference in coordination abilities between dominant and non-dominant hand in comparison with non-drummers.

References


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