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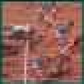


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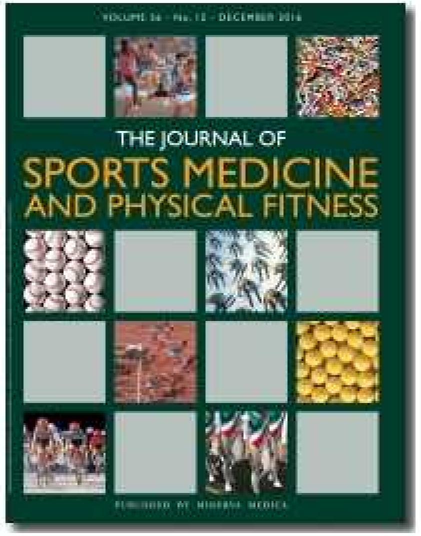

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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

Decreased interlimb differences in female basketball players

Selcuk AKPINAR

Department of Physical Education and Sport Education, Faculty of Education, Nevşehir Hacı Bektaş Veli University, Nevşehir, Turkey

Corresponding author: Selcuk Akpinar, Department of Physical Education and Sport Education, Faculty of Education, Nevşehir Hacı Bektaş Veli University, Nevşehir 50300, Turkey. E-mail: selcukbos@gmail.com

ABSTRACT

BACKGROUND: Hand preference can be influenced by some factors like sensory information and sports participation. In many sports, it is always desirable to have the similar performance of both hands to adapt to the fast changes of the game. Elite basketball players use their left non-dominant hand more accurately and more frequently during the game compared to amateurs. However, there is no quantitative data to explain this phenomenon. The aim of the study was to test whether participation of long-term basketball training influences interlimb difference and also observed more accurate and more frequent usage of the non-dominant hand in basketball players that can be explained by some kinematic variables during an aiming task.

METHODS: Professional right-handed female basketball players and age-matched non-athletes were asked to reach one of three targets in a virtual reality environment setup with either their non-dominant or dominant hand. Two kinematic parameters depicting motor performance asymmetries were measured: accuracy and hand path deviation from linearity (HPDL).

RESULTS: No interlimb differences for basketball players but significant asymmetrical performance for non-athletes were observed. Although the aiming task used in this study is not a basketball specific task, basketball players still displayed better performance compared to non-athletes in both accuracy and HPDL.

CONCLUSIONS: The current study implies that not only sensorimotor information but also participation of long-term sports activity can modify interlimb difference. Moreover, basketball players having symmetrical motor performance of both hands, which was found in this study, can indirectly explain the more frequent usage of the non-dominant left hand in basketball players.

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Key words: Basketball - Motor skills - Biomechanical phenomena – Athletes.

While on gross inspection the human body appears anatomically symmetric, asymmetry is a basic organizing principle of the human nervous system.[1] Anatomical asymmetries in the hands,[2] feet,[3] eyes [4, 5] and ears [5, 6] are generally small. However, functional asymmetries in the nervous system can result in substantial behavioral asymmetries, including human handedness.

There is little doubt that handedness reflects asymmetries in neural function rather than anatomical asymmetries in the arms and hands. However, little is currently known about the neural mechanisms that give rise to handedness. In fact, there is controversy about how to define handedness. Some describe it as a preference for using one or the other hand for specific tasks, such as writing,[7] while others suggest that the main characteristic of handedness is a difference in performance characteristics between the two limbs.[8-10]

Regarding the performance differences between arms, it has been stated that in right-handed, healthy individuals the dominant arm has better movement coordination compared to the non-dominant arm during aiming movements.[11] In fact, a recent study has also shown that sensory information influences the motor performance of the dominant and non-dominant arm differently during an aiming task, and consequently, the arm selection pattern was modified in the same task.[12] According to this study, whereas right arm performance is better when there is available visual feedback during an aiming task, the left arm displayed better accuracy than the right arm when the visual feedback is occluded. This sensorimotor performance difference resulted with the modulation of the arm selection pattern from visual feedback to no-visual feedback condition. Thus, each arm showed superior performance with respect to the sensory information related to the task and was selected more in different conditions. This suggests that arm or manual preference is not a predetermined factor,[13] but rather can be modulated by sensorimotor information.[14, 15] Moreover, some researchers have also suggested that intensive practical training can influence hand preference.[16] In line with this proposition, some researchers reported that motor preferences as well as the cortical representations of the body are not predetermined entities but can be adapted through experience, for instance sport or musical practice.[17] Moreover, some studies have shown that physical exercise and sports-specific training can positively influence neurophysiological characteristics of the brain.[18] This can modify the sensorimotor performance of both arms during the aiming movements, which may result with the decreased interlimb difference. Basketball can be a good example, which may make a change in the sensorimotor performance of both arms as players in basketball practice with both arms during their exercise settings. If the basketball player can handle the ball with similar or equal proficiency using both the non-dominant and dominant hand, he or she can adapt to the fast changes of play and will have an advantage compared to other players who do not have this bilateral competence. Therefore, in order to be successful and to find the optimal solutions for the quick pace of the game, basketball players should practice many movement skills with both hands until they experience little difference in performance when using the non-dominant hand. This may be one of the important factors to reach the professional level in basketball.[19] In fact, Stöckel *et al.* in their study stated that professional basketball players use their left, non-dominant hand more accurately and more frequently during the game compared with amateurs. They found higher proficiency for non-dominant hand actions in elite basketball players and thus, reduced interlimb asymmetry.[20] These authors analyzed the basketball games and compared the passes and shots performed with the non-dominant and dominant hand. However, they did not have any quantitative data to explain their results and if their results were related to the sensorimotor performance differences or symmetries of the arms. Moreover, as it has been shown that sensory information related to the moving arm can influence interlimb difference,[12] here it was questioned whether long-term sports training can also modify this difference. Thus, the purpose of this current study was to investigate if female basketball players have decreased interlimb difference compared to age-matched non-athletes. As the game of basketball includes the usage of both hands and, in particular, more accurate usage of the non-dominant hand in elite basketball players compared to amateurs, it has been hypothesized that elite female basketball players should demonstrate an increase both hands performance and decreased interlimb difference compared to non-athletes. To test this hypothesis, a task was implemented that required aiming toward a target with either hand and aimed to investigate whether elite female basketball players have decreased interlimb difference compared to non-athletes.

Materials and methods

Participants

Nine healthy female basketball players aged between 18-29 (M_{age}=22.5±3.7 years, M_{height}=1.79±0.06 cm, $M_{body\ weight}$=74.85±6.5 kg) and nine healthy female non-athletes aged between 18-26 (M_{age}=21.6±2.5, M_{height}=1.62±0.03 cm, $M_{body\ weight}$=59.86±2.5 kg) voluntarily participated in this study. All participants signed the consent form approved by the Institutional Review Board of Nevsehir Haci Bektas Veli University, which was in accordance with the Declaration of Helsinki as amended by the World Medical Association Declaration of Helsinki.[21] Basketball players experience ranged between 6-14 years (Mean =9.5, SD=3.04) and they are all currently playing in a team in the second division of the Turkish Basketball Federation. Non-athletes reported no participation in any sports. All participants across both groups reported right-handedness and scored above 65% on the extended 35 items handedness questionnaire,[22] which is similar to the widely known Edinburgh Inventory.[7]

Experimental setup and design

The participants were seated at a table with a sensor of the electromagnetic movement tracker (TrakSTAR, Ascension Technology, Shelburne, VT, USA) attached to their right or left forearm, depending on which arm would be measured (Figure 1). This system has been used in many studies [23-25] and has an accuracy rate of 1.4 mm root mean square (RMS) and 0.5 degrees RMS (TrakSTAR). Thus, this system is valid and reliable to measure the human movements in both 2D and 3D. This setup measured aiming in the 2D horizontal space in front of the participant. Participants' arms were covered by a mirror onto which one cursor, one start position for each hand, and targets were projected from a 55" flat screen TV, which displayed a custom, virtual reality interface. The participants seated 20 cm away from the TV. The cursor was associated with the index finger of each arm, and its position on the screen was updated in real time, limited to the TV screen's update speed of 100 Hz. Data of finger displacement was recorded at 100 Hz frequency during participants' movements.

The participants were asked to reach one of the three targets with three different directions (30º, 60º, and 90º, Figure 2). Even though there were 3 targets, one of them was displayed to the participant for each trial. The start position was displayed as a 2 cm diameter circle and placed 20 cm away from the body midline to the left or right side for each arm. Each target was displayed as a 3.5 cm diameter circle. The cursor was displayed as a 1.6 cm diameter circle with a cross hair representing the tip of the index finger. The distance between the start circle and target was set to 30 cm so that each participant could reach the target easily. After positioning the cursor in the start circle for 300 ms, the audio-visual "go" signal was triggered, and participants would move to the target. Each target was displayed earlier, after completion of the previous trial, to allow participants to self-pace trial preparation with unlimited time for planning the movement. Participants could take a break during the experiment in order to avoid fatigue. This break was the same for all participants and was one minute in duration. To prevent the interlimb transfer, participants were asked to reach the targets with one arm in a session and they were asked to come to the lab again to test the other arm in the other session (at least three days gap between sessions).

Experimental task

Participants were asked to perform 60 aiming movements (20 per target) from the start circle (2 cm in diameter) to the target (3.5 cm in diameter), which were presented in randomized order. Participants were instructed to reach the target rapidly, while maintaining accuracy, and stop on the target with no additional cor-

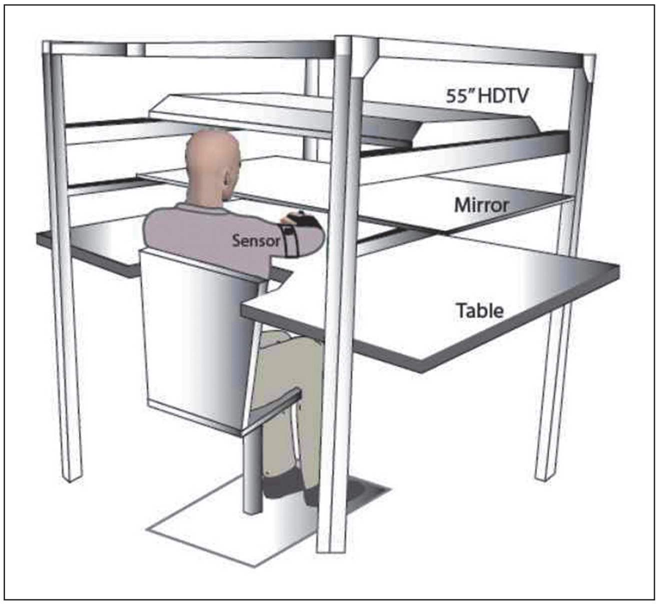

Figure 1.—Experimental setup.

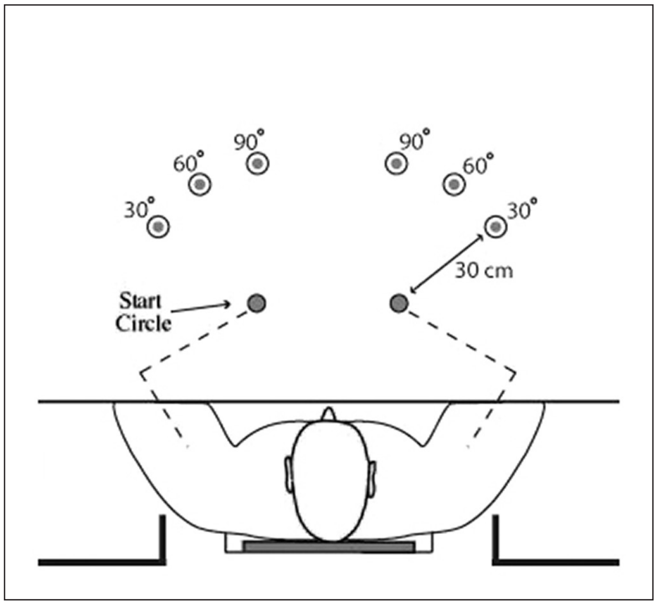

Figure 2.—Target layout.

rections. Trials were 1 sec in duration and were initiated with the beep signal after the cursor (1.25 cm in diameter cross hair) was held in the start circle for the duration of 0.3 seconds. A speed requirement for the aiming movements was initiated to ensure all the participants moved with similar speed. This is because speed may have an effect on the accuracy or hand path deviation from linearity. Thus, the same instruction was given to all participants. Results for movement speed indicated that there was no difference between the two arms for the two participant groups, basketball players dominant arm mean =0.73±0.08 m/s non-dominant arm mean =0.74±0.10 m/s and non-athletes dominant arm mean =0.71±0.11 m/s non-dominant arm mean = 0.73±0.11 m/s, and the differences in the dependent measures reflect differences in inter-segmental joint coordination. Accuracy was rewarded with 10, 3 and 1 point for landing within 3.5, 4.5 and 5.5 cm diameter from the center of the target respectively. These points were provided to motivate the participants during the experiments and provide immediate feedback as to their accuracy in reaching the targets.

Statistical analysis

In order to determine interlimb differences in the quality of movement performance, we quantified two dependent measures: movement accuracy (Final Position Error [FPE]) and movement quality (Hand Path Deviation from Linearity [HPDL]). The FPE was defined as the Euclidian distance between the center of the target and the 2D final position of the tip of the index finger. The HPDL was defined as the ratio between the minor and the major axis of the movement path of the index finger (hand path). The major axis was defined as the longest distance between any of two points on the hand path, and the minor axis was defined as the shortest distance perpendicular to the major axis. The collected data were analyzed using Matlab software, and the accuracy and linearity of each aiming movement were calculated.

Three-way mixed model ANOVA (target directions; 30º, 60º, and 90º x group; basketball players and non-athletes x arms; right and left) was used to investigate if basketball players have less interlimb difference at one of three different targets compared to non-athletes. *Post-hoc* analysis was conducted using Bonferroni adjustment. Assumptions for the mixed model ANOVA were checked before running the analysis for each dependent variable, and no violations were found. Significance level was tested at $P<0.05$.

Results

Both groups, basketball players and non-athletes, made reaches to the three different targets located across horizontal space in front of the body with the dominant and the non-dominant arm. Figure 3 shows the average magnitude of the final position error (FPE) for each target for the dominant (black half circles) and the non-dominant arm (gray half circles) across basketball players and non-athletes. The result of the statistical analysis for the FPE displayed a significant group and arm, $F(1, 16)=3.99$, $P<0.05$, $\eta^2=0.28$; group and target direction interactions, $F(1, 16)=4.68$, $P<0.05$, $\eta^2=0.32$. *Post-hoc* analysis for group x arm interaction displayed that both non-dominant (ND) and dominant arm (D) of basketball players had significantly better accuracy (ND arm M=1.05±0.14 cm and D arm M=1.02±0.28 cm) compared to either arm of non-athletes (ND arm M=3.07±1.53 cm and D arm M=2.45±1.18 cm) ($P<0.05$). Moreover, although there was no significant difference between the non-dominant and dominant arm of basketball players in FPE ($P>0.05$), the dominant arm had significantly less FPE than the non-dominant arm in non-athletes ($P<0.05$). *Post-hoc* analysis for group x target directions showed that basketball players performed with significantly better accuracy in all target directions compared to non-athletes ($P<0.05$).

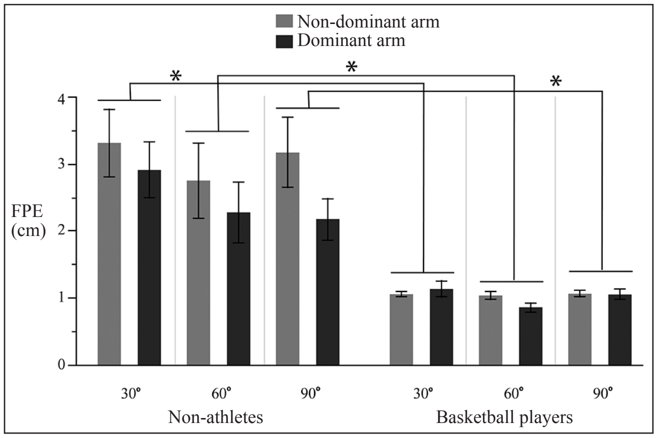

Figure 3.—Final position error (FPE), non-athletes and basketball players averaged across targets and arms.

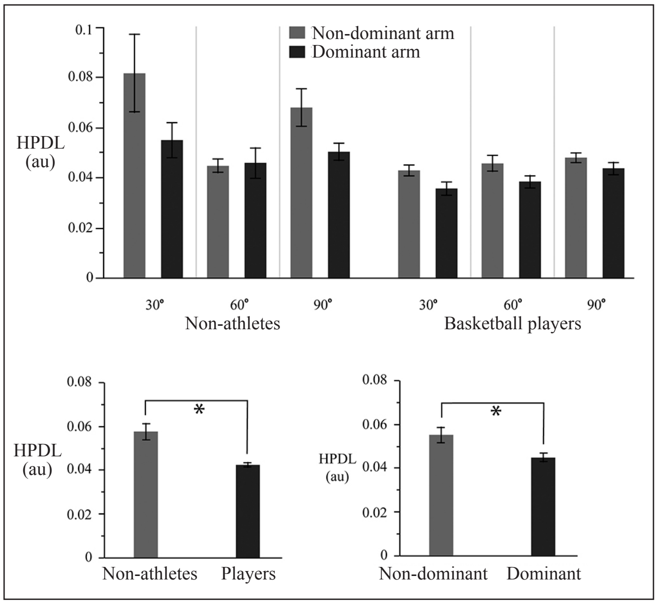

Figure 4.—Hand path deviation from linearity (HPDL). A) Non-athletes and basketball players averaged across targets and arms; B) non-athletes and basketball players averaged between arms; C) averaged between arms.

The average magnitude of the hand path deviation from linearity (HPDL) for each target direction across basketball players and non-athletes was displayed in Figure 4. The result of three-way mixed model ANOVA displayed only significant main effect for group, $F(1, 16)=8.05$, $P<0.01$, $\eta^2=0.41$ and arm, $F(1, 16)=10.67$, $P<0.01$, $\eta^2=0.52$. Basketball players performed significantly less curvature movements than non-athletes (M=0.042±0.008 and M=0.057±0.02, $P<0.05$, respectively). The main effect of arm revealed that the dominant arm overall moved significantly straighter than the non-dominant arm (M=0.044±0.01 and M=0.055±0.02, $P<0.05$, respectively).

Taken together, female basketball players displayed a reduction of interlimb differences in FPE and better performance in both FPE and HPDL.

Discussion

In this study, it was questioned whether elite female basketball players and female non-athletes display different lateralization profiles during a simple aiming task. It has been previously stated that changes in sensorimotor performance in response to visual feedback conditions, *e.g.* performing aiming movements with vision *vs.* no vision, had an effect on lateralization.[12] Studies also reported that not only unimanual practice with the non-dominant arm [26, 27] but also bimanual practice [16, 20] can modulate the interlimb asymmetry between arms. In a very recent study, it has also been found that unimanual athletic training predominantly with the right arm can improve the performance of the left arm during an aiming task.[28] Thus, based on the studies above, it was expected that long-term basketball practice (greater than 6 years) might increase limb performance not only for the dominant but also for the non-dominant arm.

As it was predicted, results showed that female basketball players performed more accurate reaches with both arms when compared to female non-athletes. Moreover, their movements were significantly straighter than that of non-athletes' movements. Regarding the interlimb differences, whereas female basketball players showed similar performance of the non-dominant and dominant arm in FPE, female non-athletes displayed better performance with the dominant arm, thus an interlimb difference was observed. To our knowledge, there is no study comparing the interlimb difference for the arms among basketball players. However, it has been recently found that basketball players displayed better balance performance with their dominant leg compared to their non-dominant leg.[29] On the other hand, no significant difference was found between the dominant and non-dominant leg in the measurement of the isokinetic knee strength among elite young basketball players.[30] Thus, dominant and non-dominant leg and hand performances could be dependent on the applied measurements.

Basketball is a good example where both non-dominant and dominant hands are used in the game. In fact, one of the most important requirements for the players in basketball is to be able to use both hands efficiently and frequently. By this way, players can surely adjust their movements to fast changes in the game. That is why basketball coaches try to have their players practice most of the skills with both hands in their practice. In their study, Stöckel *et al.* referred to this phenomenon as the *athlete's individual bilateral competence* and suggested that if the athletes want to be successful in their sports, they should have a certain degree of bilateral competence. Thus, performing the skills efficiently in basketball requires an expertise, which could be done with effective bimanual action of the arms. In this respect, decreased interlimb difference found in this study can be associated to the idea of the *athlete's individual bilateral competence.*[20]

Superior performance of any athletes can be linked to some neurophysiological characteristics. Neurophysiological characteristics help determine superior athletes' level of performance in that athletes' brains must adapt their behaviors to perform skilled movements under different and changing environment.[19] Such neural activities in the brain include perception, decision-making, motor preparation, and execution of the movement. Several studies reported changes and shifts in brain activity due to long-term practice among both musicians [31] and athletes.[32] Thus, the brain shows great plasticity in its ability to acquire skills over the long-term, and in turn to improve performance when executing skilled movement, as this study notes. Indeed, long-term bimanual practice with both arms improves the cortical activity in both hemispheres of the brain. The improved neural activity that this produces may then in turn result in superior performance of perception, decision-making, motor preparation, and in the execution of the movement for both arms in basketball players when compared to non-athletes. Other researchers have similarly noted bimanual training benefits in improving interlimb coordination between both limbs in rehabilitation contexts.[27] Virtual tracking of arm aiming also demonstrated the benefits of bimanual training noting improvements in both single limb performance with the dominant arm and in performing bimanual movements.[33] Thus, long-term basketball training should have an effect on some motor parameters among the players.

Conclusions

Sports like basketball, in which both arms should be used for dribbling, passing, and shooting, can modify the human laterality and possibly affect the brain control mechanism and thus decrease the asymmetry between arms. In conclusion, not only the sensorimotor information related to the task,[12] but also bimanual training like basketball can modify the sensorimotor performance asymmetries and thus interlimb differences. Moreover, decreased lateralized skill-performance observed in elite basketball players [20] can be explained by decreased sensorimotor performance, which was found in this study. It could be suggested that decreased interlimb difference should be required to be a good basketball player apart from the anthropometric indices and that it could also be used for the talent identification.[34]

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