Monten. J. Sports Sci. Med. 3 (2014) 2: 33–38
Review Paper
UDC 796:159.943.75

Why Left-handers/footers are overrepresented in some sports?

Selcuk Akpinar
Nevşehir Hacı Bektaş Veli University, Faculty of Education, Department of Physical Education and Sport Education, Nevşehir, Turkey
Bilal Bicer
Hatay Mustafa Kemal University, School of Physical Education and Sport, Hatay, Turkey

A B S T R A C T

Left-handers/footers are found with disproportionately more frequency in many interactive sports compared to the general population. In ıorder to point out this issue, we firstly mentioned about handedness in general and secondly the origin of handedness. Based on the studies in the literature, we then gave examples about the anatomical correlation of handedness. Finally, some explanations were provided to explain the higher rate of lefties in some sports compared to the general population. Regarding the last issue, researchers stated that there are mainly two possible hypotheses to explain this phenomenon; innate superiority and negative frequency hypothesis. Besides those hypotheses, we should also consider that there is a need to have left handed/footed players in some sports to get more tactical advantages. We tried to give some examples regarding those ideas. The studies in the literature state that left handed/footed players, in fact, have both tactical and perceptual advantages in some interactive sports and thus, overrepresented in those sports compared to the general population.

Key words: *Left handedness/footedness, sports, tactical advantage, and perception.*

Handedness

While on gross inspection, the human body appears anatomically symmetric, asymmetry is a basic organizing principle of the human nervous system (Gazzaniga, 1989). Anatomical asymmetries in the hands (Hardyck & Petrinovich, 1977), feet (Brown & Taylor, 1988), eyes (Bourassa, McManus, & Bryden, 1996; Hebbal & Mysorekar, 2003) and ears (Hebbal & Mysorekar, 2003; Jung & Jung, 2003) 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, a 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 has a preference for using one or the other hand for specific tasks, such as writing (Oldfield, 1971), while others suggest that the main characteristic of handedness is a difference in performance characteristics between the two limbs (Goble & Brown, 2008; Sainburg, 2002).

It well established that most humans are right-handed, and that the incidence of left- or right-handedness can vary slightly across different cultures (Perelle & Ehrman, 2005). According to cross cultural statistical studies, approximately 88 to 95% of the population from different countries and cultures is right-handed and prefer to use the dominant hand for activities such as throwing or writing (Caliskan & Dane, 2009; Jung & Jung, 2009; Perelle & Ehrman, 1994; Vuoksimaa, Koskenvuo, Rose, & Kaprio, 2009). Singh and Bryden (1994) reported differences in handedness between Canadians and Indians. Those two countries were expected to have very different distribution of handedness because of differences in social pressures to use right hand, which were higher in India. The rate of right-handedness was found to be 90.2% in Canada and 94.8% in India. Similarly, the rate of handedness in Japan, where social pressures are also higher, was shown to be higher than that of Canada (Ida & Bryden, 1996). McManus (2009) used a meta-analysis to draw a map, comparing the distribution of handedness between regions of the USA and many European countries. The variation in handedness across the selected regions changed only about 5%.

Considering the discrepancy of methods used for assessment of handedness or type of criterion used for categorization of handedness, it is generally thought that about 90% of the general population is right-handed (Previc & Saucedo, 1992). Surprisingly, this proportion of right-handed people has remained stable across geographical locations and cultures (Goble & Brown, 2008). Similar to human right hand bias, chimpanzees and other animals often prefer to use one hand or paw for particular actions (Bradshaw & Rogers, 1993). For instance, the work of Hopkins and Leavens (1998) has shown that adult chimpanzees significantly gestured with their right hand than with their left hand which shows the evidence for lateralization and right hand bias among chimpanzees. Thus, both humans and some animals show a strong preference for the right hand for several actions. In fact, this right hand bias for humans has maintained over the course of time by most of the population. Markers of hand preference in prehistory are found in material culture from the actions of lateralized tool manufacture and use that leave traces on objects, and in fossil skeletal asymmetries resulting from asymmetric use of the upper limb muscles over an individual's lifetime (Uomini, 2009). For example, Latimer and Lowrance (1965) conducted a research on the weights and lengths of the right and left bones of each pair from 105 human skeletons from Asia. In general, they found that all of the long

Received for publication July 9, 2014

bones of the upper extremity were heavier and longer on the right side. The left bones were more variable in weight and length. The upper extremity and its bones noticeably had more asymmetry than the lower (Hebbal & Mysorekar, 2003). For the past 5000 years the best historical data are the study by Coren and Porac (1977), which looked at five millennia of artistic representations of unimanual motor activities (such as playing board games, throwing spears, writing, etc.). Overall about 92% of paintings, drawing, and sculptures show the right hand being used, with little variation over the entire period of recorded history. Thus, even in ancient cultures, humans were predominantly right handed.

Origin of Handedness

As highlighted above, handedness has been studied for years and many theories of the origin of handedness have been proposed, however, answer for the "what determines handedness" is not clearly known. The list of factors that has been proposed to explain handedness is very large. For instance, some researchers attributed left-handedness with pathological disorders. Pathological left-handedness hypothesis has gained some support with higher frequency of left-handedness in schizophrenic patients and after childhood meningitis (Dragovic & Hammond, 2005; Ramadhani, Koomen, Grobbee, van Donselaar, Marceline van Furth, & Uiterwaal, 2006; Satz & Green, 1999). Besides this, a study showed that the rate of left-handedness was two times more common in infants who had required resuscitation after delivery (Williams, Buss, & Eskenazi, 1992). However, in contrast to Williams et al. study, Bailey and McKeever (2004) stated that only maternal age had a weak association with left-handedness. Moreover, result of some studies did not show a shift towards using left hand more frequently in schizophrenic patients (Malesu, Cannon, Jones, McKenzie, Gilvarry, Rifkin, Toone, & Murray, 1996: Taylor & Amir, 1995) so that pathological left-handedness hypothesis was not supported.

Some researchers have attempted to explain the determinants of handedness with looking at the handedness prevalence in singletons, twins, and triplets. Even though in a recent study of large number of twins and their siblings, Medland and his colleagues (2003) found no difference in left handedness between twins and singleton sibs (Medland, Wright, Gaffen, Hay, Levy, Martin, & Duffy, 2003), many studies found increased left-handedness in twins and triplets compared to singletons (Sicotte, Woods & Mazziotta, 1999; Vuoksimaa, Koskenvuo, Rose, & Kaprio, 2009; Williams, Buss & Eskanazi, 1992). Some speculate that the higher incidence of left-handedness in twins could be the smaller birth weight in twins than singletons and more stressful pregnancy and traumatic delivery (Sicotte, Woods, & Mazziotta, 1999; Vuoksimaa et al., 2009). As the gestation is the main determinants of birth weight in twins, they are born about 1 kg lighter at birth than singletons. Therefore, observed difference in prevalence of left-handedness between twins and singletons might partially have arisen from the lower average birth weight in twins. However, there is no much clear evidence and support for this idea and association between handedness and birth weight was found weaker (Medland et al., 2003). The controversial results in the literature also leave a question about the prevalence of handedness in twins. Besides, even if we think that stressful and traumatic pregnancy can account for some left-handedness, not all left-handedness does have a pathological origin (Vuoksimaa et al., 2009).

Additionally, it can be speculated as well that the typical uterine position of a fetus during the end of pregnancy can also be caused by the earlier formation of handedness. Many studies have observed handedness postnatally, but some ultrasound studies propose that the formation of handedness takes place prenatally. Researchers found right hand preference, in the form of thumb sucking, in fetuses at 10 weeks gestational age (Hepper, McCartney, & Shannon, 1998). Prenatal thumb sucking has also been found to be related to postnatal handedness at age 10 – 12 (Hepper, Wells, & Lynch, 2005). Thus, these ultrasound studies emphases the early formation of human handedness.

Helper et al. (1998) emphasized the relationship between handedness and the age of subjects. They hypothesized that left-handers die at an earlier age than right-handers, and have a greater number of accidents. This hypothesis is controversial and there are some criticisms about the methodology, and failures to replicate empirical claims (Seddon & McManus, 1993). On the other hand, there are general agreements that the incidence of handedness seems to decrease with age and have increased in recent years (Strang, 1991; McManus, 2009).

Francks et al. (2007) recently made a claim to have identified the first potential genetic influence of human handedness. They have found a gene, LRRTM1 (Leucine-rich repeat transmembrane neuronal 1), that increases the likeliness of being left-handed (Francks et al., 2007). Even though this is the first concrete evidence for a genetic determinant of handedness, this claim gained a critic on the basis that the authors have made unjustified assumptions concerning mode of transmission both of psychosis and relative hand skill that they have failed to establish a parent of origin effect (Crow, Close, Dagnall, & Priddle, 2007). Thus, the origin of handedness is unlikely to be resolved.

The world is made up for the right-handed people. According to the theory which was proposed by Porac and Coren (1981), the general physical environment is in favor of the right-handers. Almost up to 98% of the equipments in every society are designed for right handed people. Examples for those equipments can vary from simple kitchen tools like can openers and utensils to very technological devices like camcorders and cameras. Moreover, left-handers have so many inconveniences in everyday facilities geared for the right-handers: handle position and opening/shutting direction of doors, key holes, position of cash and vending machines buttons, car engine keyholes, gearshift sticks, etc. Because most of those devices are made for right-handers, left-handers have to twist his or her left arm or switch to his or her non-dominant right arm in an unnatural way. We can also hear an offer by our left-handed friend at the table during lunch to sit at the far left end so that he or she will be comfortable during the meal.

There is also some suggestion that handedness may sometimes be the result of socio-cultural and environmental factors. In fact, there are some reports stating that relatively large numbers of adult left-handers have experienced attempts to switch writing hand to the right side (Porac & Searleman, 2002; Porac & Martin, 2007; Searleman & Porac, 2001). Moreover, Perelle and Ehrman (1994) also stated that parents discourage their children to use their right hand in one of the East Asian culture. However, it is very difficult to change hand preference especially at an early age. Indeed, most attempts to change handedness fail, and the process is bound to be difficult, or motor performance skill performance remains worse than originally preferred hand. Overall, although the determinants of human handedness are not clearly known, it seems most likely that both nature (genetics) and nurture (environment) play a considerable role and make a good combination to explain handedness.

Handedness can be related to some anatomical parameters in the brain

Researchers have undertaken potential anatomical substrate for handedness at both macroscopic and microscopic levels. One study using magnetic resonance morphology showed that the depth of the central sulcus was related to handedness: in right-handers the left central sulcus was deeper than the right, and the opposite pattern was shown for left-handers (Amunts et al., 1996). Furthermore, this macroscopic asymmetry was accompanied by microscopic differences in neutrophil volume, with a greater volume in the hemisphere contralateral to the preferred hand. The authors posit that handedness is associated with more profuse horizontal connections (reflected by the greater neutrophil volume), and the increased intrasulcal surface of the precentral gyrus which may provide a potential substrate for the more complex movements performed by the preferred hand (Amunts et al., 1996). Volkmann et al. (1998) in their study using magnetoencephalography found a significant increase in the volume of the primary motor cortex contralateral side of the preferred hand (Volkmann, Schnitzler, Witte, & Freund, 1998). The results of these studies show asymmetries of neural structures in motor cortex.

Another study looked at the effects of handedness and gender on the depth of the central sulcus in the area of cortical hand presentation (Amunts, Jancke, Mohlberg, Steinmetz, & Zilles, 2000). Strongly male right-handers were found to have a significantly deeper left central sulcus than right central sulcus. Interestingly, the difference in the depth of the central sulcus between the hemispheres was found to decrease significantly from strongly male ri ght-handers, to non-strongly male right-handers, to strongly male left-handers. Even though the same effect was found for the left-handers, 62% of the strongly left-handers had a deeper right central sulcus, this effect was not found significant for the group as a whole. Interestingly, this interhemispheric asymmetry for the central sulcus was not found for the females (Amunts et al., 2000). The results of this study suggest that both the degree of handedness and gender differences may also affect the cortical organization of hand movements.

There are also some TMS studies in the area of motor cortex to find the threshold for eliciting a motor response in different intrinsic and extrinsic muscles of preferred and non-preferred arms. Generally, those works showed that a lower threshold of contralateral brain stimulation is needed to activate preferred arm musculature (Macdonell et al., 1991; Triggs, Calvanio, Macdonell, Cros, & Chiappa, 1994). However, other studies did not show the same asymmetry between preferred and non-preferred arm musculature activation during the brain stimulation (Cicinelli, Traversa, Bassi, Scivoletto, & Rossini, 1997; Civardi, Cavalli, Naldi, Varrasi, & Cantello, 2000). Additionally, TMS has also been used as a means of mapping the extent of various hand and arm representations in the motor cortex. One prominent in this area was conducted by Triggs et al. (1999). They quantified the number of cortical sites eliciting a motor response in two different arm muscles of left and right arms. They found that right-handed subjects had a larger cortical area in the left hemisphere assigned to the targeted muscles than that seen in the right hemisphere which is also consistent with the other studies where used different techniques to map the cortical areas in the brain. In summary, although asymmetries in both brain structures and activations are correlated to handedness, both cerebral hemispheres appear to contribute to unilateral arm and hand movements. The left hemisphere has long been recognized as being dominant for the motor control of skilled voluntary movements in most right-handed individuals; however right hemisphere superiority has also been shown for certain motor functions. Manual asymmetries, as they are observable behaviors, can therefore provide insight into the organization and functioning of the brain.

Left-handers/footers in the sports

As stated above, whereas left-handers/footers represent about 10-12% of the general population (Caliskan & Dane, 2009; Perelle & Ehrman, 1994), they are found with disproportionately more frequency in interactive sports (Loffing, Hagemann, & Strauss, 2010). In fact, when we look at the many interactive sports, we can see that left-handed/footed athletes are over represented compared to general population. For instance, tennis (Holtzen, 2000), baseball (Goldstein & Young, 1996), cricket (Brooks, Bussière, Jennions, & Hunt, 2004), fencing (Harris, 2010), volleyball (Loffing, Schorer, Hagemann, & Baker, 2012) are some interacitve sports to have higher rate of left-handed/footed athletes compared to general population. However, this over representation of left-handed/footed athletes cannot be seen in non-interactive sports, such as gymnastics, darts, and archery (Grouios, 2004). We can also give some specific examples from different sports and different clubs. For example, football clubs in Europe in 2013-2014 season; Real Madrid (Spain) had 2 left-footed players in their first team which equals to 18% among the total players in the team, Barcelona (Spain) had again 2 left-footed players in their first team which equals to 18% among the total players in the team, AC Milan (Italy) had 3 left-footed players in their first team which equals to 27% among the total players in the team, Arsenal (England) had 4 left-footed players in their first team which equals to 36% among the total players in the team, Besiktas (Turkey) had 3 left-footed players in their first team which equals to 27% among the total players in the team. Moreover, in team handball for instance, there should be at least 2 heft-handed players in the team to have more tactical advantage during the game and this equals to 28.5% among the total players in the team. In 2013-2014 season in National Basketball Association (NBA), USA, there are 60 left-handed basketball players which equals to 13.3% compared to total of 450 players in the NBA. According to the examples above, it can be said that the incidence of left-handedness/footedness can change from 13% to 36% depending on the type of sport. It is still worthy to point out that this ratio is substantially more compared to general population. In fact, in a recent study by Loffing et al. (2012), it has been stated that the representation of top level left-handed tennis players has decreased over the years compared to past. When we look at 20-30 years back from now, we can see many left-handed top level tennis players like, Monica Seles, Martina Narvatilova, Goran Ivanisevic, Jimmy Conors and etc. Even though there are many factors affecting the good performance in tennis like the other sports, it was believed that left-handedness was sometimes considered beneficial. However, this left-handed players advantage in tennis is diminishing in the professional tennis. Loffing et al. (2012) explained this issue with having less left-handed tennis players in the past compared to right-handed counterparts. With the more participation of left-handed players in tennis, right-handed players have had a chance to get more experience playing against a lefty. However, there are still more proportionate of left-handed tennis players in the amateur level.

It is very clear that left-handed or footed people are over represented in the sports compared to general population (13-25%

vs 8-10%). Now, we should ask a question; "is this a coincidence?". In fact, it is not; researchers tried to explain this phenomenon and reasoned the high frequency of left-handers/footers with mainly two possible hypotheses; innate superiority hypothesis (based on the perceptual and neuropsychological advantage) and negative frequency hypothesis (players having less experience with left-handed opponents) (Faurie & Raymond, 2005).

Left-handers/footers have generally more advantage over right-handers due to better neuropsychological predispositions. Researchers found that spatiotemporal visual perception areas which is required for attention is located in the right hemisphere (Heilman & Van Den Abell, 1980). Moreover, it has been also stated that left hand has faster reaction time even among the right-handed people (Barthélémy & Boulinguez, 2001; Boulinguez & Barthélémy, 2000) and better anticipation skills (Rodrigues, Vasconcelos, Barreiros, Barbosa & Trifilio, 2009). Cherbuin and Brinkman (2006) study kind of approve those results mentioned above with the support from anatomical data. Cherbuin and Brinkman (2006) concluded that left-handers' brains are more symmetrical with larger and more efficient connections between the two hemispheres. Thus, they are better at processing information across the two sides of the brain. This allow them to display better performance in some certain skills compared to right-handers. Besides the explanation of perceptual and neuropsychological advantage of left-handers/footers for the over representation in some sports, some other researchers also reasoned to have higher ratio of left-handedness/footedness in various sports with the negative frequency hypothesis (Faurie & Raymond, 2005). This hypothesis mainly states that left-handed/footed players have the superiority in interactive sports compared to right-handed/footed counterparts as the right-handed/footed players have less experiences with the left-handed/footed counterparts in the game. This results with a disadvantage to develop a tactical approach for the right-handed/footed players. For instance, Hagemann (2009) showed that both left- and right-handed tennis players with different experience level (expert, intermediate, and novice) predicted better the direction of strokes by right-handed players. He explained this result with the set of strategic advantages of left-handers in sport which partially supports the negative frequency hypothesis. The similar result was also observed among volleyball players. Loffing et al. (2012) had skilled (n=18) and novice (n=18) players to predict shot directions of left- and right-handed players attacks in a video-based anticipation task. They showed that the outcome of left-handed players' actions was significantly less accurately predicted compared to that of right-handed players' attacks. The authors explained the result with players having less experience with left-handed opponents in the game, thus may not develop visual perception with the encountered left-handed actions. These mentioned two studies' results imply that having less experience with left handed/footed opponents can be a shortage for the right handed/footed players to develop some certain visual perceptions to get more successful in the game. Besides this, researchers showed that tennis players normally try to hit the ball to their right irrespective of their opponent's handedness (Loffing et al., 2010). This will surely give an advantage to left-handers as they will return the ball with forehand technique.

In addition to two hypotheses stated above, we should also consider another point of view regarding the need of lefties in some sports. For instance , there should be at least 2 left-handed players in the team who position on the right side of the court to get more angle when they shot the ball to the goal in team handball. These two left-handed players play on the right backcourt and right wing positions. The main reason to have lefties in those positions because they can have wider goal angle when they shot to the goal. This can most probably increase the rate of scoring during the game. This can be also counted as a tactical advantage of lefties in the sports and can be also another reason to have more rate of lefties in the sports.

In conclusion, researchers explain the phenomena of left handers/footers being overrepresented in many interactive sports compared to general population with mainly two hypotheses. These are innate superiority hypothesis and negative frequency hypothesis (Faurie & Raymond, 2005). Moreover, it can be also stated that there is also a need to have left handers/footers in some sports to get better tactical advantage during the game. Thus, both hypotheses and the idea of tactical advantage of lefties elucidate the reason of overrepresentation of lefties in many interactive sports.

REFERENCES

Amunts, K., Jancke, L., Mohlberg, H., Steinmetz, H., & Zilles, K. (2000). Interhemispheric asymmetry of the human motor cortex related to handedness and gender. *Neuropsychologia, 38*(3), 304-312.

Amunts, K., Schlaug, G., Schleicher, A., Steinmetz, H., Dabringhaus, A., Roland, P. E., et al. (1996). Asymmetry in the human motor cortex and handedness. *Neuroimage, 4*(3 Pt 1), 216-222.

Bailey, L. M., & McKeever, W. F. (2004). A large-scale study of handedness and pregnancy/birth risk events: implications for genetic theories of handedness. *Laterality, 9*(2), 175-188.

Barthélémy, S. & Boulinguez, P. (2001). Manual reaction time asymmetries in human subjects: the role of movement planning and attention. *Neuroscience Letters,* 315(1): 41-44.

Boulinguez, P. & Barthélémy, S. (2000). Influence of the movement parameter to be controlled on manual RT asymmetries in right-handers. *Brain and Cognition,* 44(3): 653-661.

Bourassa, D. C., McManus, I. C., & Bryden, M. P. (1996). Handedness and eye-dominance: a meta-analysis of their relationship. *Laterality, 1*(1), 5-34.

Bradshaw, J. L., & Rogers, L. J. (1993). *The Evolution of Lateral Asymmetries, Language, Tool Use, and Intellect*. San Diego: Academic Press.

Brooks, R., Bussie`re, L. F., Jennions, M. D., & Hunt, J. (2004). Sinister strategies succeed at the cricket World Cup. *Proceedings of the Royal Society of London B*, 271, 64–66.

Brown, E. R., & Taylor, P. (1988). Handedness, footedness, and eyedness. *Percept Mot Skills, 66*(1), 183-186.

Caliskan, E., & Dane, S. (2009). Left-handedness in blind and sighted children. *Laterality, 14*(2), 205-213.

Cicinelli, P., Traversa, R., Bassi, A., Scivoletto, G., & Rossini, P. M. (1997). Interhemispheric differences of hand muscle representation in human motor cortex. *Muscle Nerve, 20*(5), 535-542.

Civardi, C., Cavalli, A., Naldi, P., Varrasi, C., & Cantello, R. (2000). Hemispheric asymmetries of cortico-cortical connections in human hand motor areas. *Clin Neurophysiol, 111*(4), 624-629.

Cherbuin, N & Brinkman, J 2006, 'Efficiency of callosal transfer and hemispheric interaction', *Neuropsychology*, 20, 2, 178-184.

Coren, S., & Porac, C. (1977). Fifty centuries of right-handedness: the historical record. *Science, 198*(4317), 631-632.

Crow, T. J., Close, J. P., Dagnall, A. M., & Priddle, T. H. (2009). Where and what is the right shift factor or cerebral dominance gene? A critique of Francks et al. (2007). *Laterality, 14*(1), 3-10.

Dragovic, M., & Hammond, G. (2005). Handedness in schizophrenia: a quantitative review of evidence. *Acta Psychiatr Scand, 111*(6), 410-419.

Faurie, C., & Raymond, M. (2005). Handedness, homicide and negative frequency-dependent selection. *Proceedings of the Royal Society of London B*, 272, 25–28.

Francks, C., Maegawa, S., Lauren, J., Abrahams, B. S., Velayos-Baeza, A., Medland, S. E., et al. (2007). LRRTM1 on chromosome 2p12 is a maternally suppressed gene that is associated paternally with handedness and schizophrenia. *Mol Psychiatry, 12*(12), 1129-1139, 1057.

Gazzaniga, M. S. (1989). Organization of the human brain. *Science, 245*(4921), 947-952.

Goble, D. J., & Brown, S. H. (2008). The biological and behavioral basis of upper limb asymmetries in sensorimotor performance. *Neurosci Biobehav Rev, 32*(3), 598-610.

Goldstein, S. R., & Young, C. A. (1996). ''Evolutionary'' stablestrategy of handedness in major league baseball. *Journal of Comparative Psychology*, 110, 164–169.

Grouios, G. (2004). Motoric dominance and sporting excellence: Training versus heredity. *Perceptual and Motor Skills*, 98, 53–66.

Hagemann, N. (2009). The advantage of being left-handed in interactive sports. Attention, Perception, & Psychophysics, 71, 1641–1648.

Hardyck, C., & Petrinovich, L. F. (1977). Left-handedness. *Psychol Bull, 84*(3), 385-404.

Harris, L. J. (2007). In fencing, what gives left-handers the edge? Views from the present and the distant past. *Laterality*: Asymmetries of Body, Brain and Cognition.

Hebbal, G. V., & Mysorekar, V. R. (2003). Anatomical and behavioural asymmetries in right and left handers from India. *Ann Anat, 185*(3), 267-275.

Heilman, K.M. & Van Den Abell, T. (1980). Right hemisphere dominance for attention: the mechanism underlying hemispheric asymmetries of inattention (neglect). *Neurology* 30:327–330.

Hepper, P. G., McCartney, G. R., & Shannon, E. A. (1998). Lateralised behaviour in first trimester human foetuses. *Neuropsychologia, 36*(6), 531-534.

Hepper, P. G., Wells, D. L., & Lynch, C. (2005). Prenatal thumb sucking is related to postnatal handedness. *Neuropsychologia, 43*(3), 313-315.

Holtzen, D. W. (2000). Handedness and professional tennis. *International Journal of Neuroscience*, 105, 101–119.

Hopkins, W. D., & Leavens, D. A. (1998). Hand use and gestural communication in chimpanzees (Pan troglodytes). *J Comp Psychol, 112*(1), 95-99.

Ida, Y., & Bryden, M. P. (1996). A comparison of hand preference in Japan and Canada. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale, 50*(2), 234-239.

Jung, H. S., & Jung, H. S. (2009). Hand dominance and hand use behaviour reported in a survey of 2437 Koreans. *Ergonomics, 52*(11), 1362-1371.

Latimer, H. B., & Lowrance, E. W. (1965). Bilateral asymmetry in weight and in length of human bones. *Anat Rec, 152*(2), 217-224.

Loffing, F., Hagemann, N., & Strauss, B. (2010). Automated processes in tennis: Do left-handed players benefit from the tactical preferences of their opponents? *Journal of Sports Sciences*, 28(4), 435–443.

Loffing, F., Schorer, J., Hagemann, N., & Baker, J. (2012). On the advantage of being left-handed in volleyball: further evidence of the specificity of skilled visual perception. *Atten Percept Psychophys*, 74(2):446-53

Macdonell, R. A., Shapiro, B. E., Chiappa, K. H., Helmers, S. L., Cros, D., Day, B. J., et al. (1991). Hemispheric threshold differences for motor evoked potentials produced by magnetic coil stimulation. *Neurology, 41*(9), 1441-1444.

Malesu, R. R., Cannon, M., Jones, P. B., McKenzie, K., Gilvarry, K., Rifkin, L., et al. (1996). Mixed-handedness in patients with functional psychosis. *Br J Psychiatry, 168*(2), 234-236.

McManus, I. C. (2009). The history and geography of human handedness. In R. S. K. Iris E. C. Sommer (Ed.), *Language Lateralization and Psychosis* (pp. 37-57): Cambridge University Press.

Medland, S. E., Wright, M. J., Geffen, G. M., Hay, D. A., Levy, F., Martin, N. G., et al. (2003). Special twin environments, genetic influences and their effects on the handedness of twins and their siblings. *Twin Res, 6*(2), 119-130.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia, 9*(1), 97-113.

Perelle, I. B., & Ehrman, L. (1994). An international study of human handedness: The data. *Behav Genet, 24*(3), 217-227.

Perelle, I. B., & Ehrman, L. (2005). On the other hand. *Behav Genet, 35*(3), 343-350.

Porac, C., & Coren, S. (1981). *Lateral Preferences and Human Behaviour*. New York: Springer-Verlag.

Porac, C., & Martin, W. L. (2007). A cross-cultural comparison of pressures to switch left-hand writing: Brazil versus Canada. *Laterality, 12*(3), 273-291.

Porac, C., & Searleman, A. (2002). The effects of hand preference side and hand preference switch history on measures of psychological and physical well-being and cognitive performance in a sample of older adult right-and left-handers. *Neuropsychologia, 40*(12), 2074-2083.

Previc, F. H., & Saucedo, J. C. (1992). The Relationship between Turning Behavior and Motoric Dominance in Humans. *Perceptual and Motor Skills, 75*(3), 935-944.

Ramadhani, M. K., Koomen, I., Grobbee, D. E., van Donselaar, C. A., Marceline van Furth, A., & Uiterwaal, C. S. (2006). Increased occurrence of left-handedness after severe childhood bacterial meningitis: support for the pathological left-handedness hypothesis. *Neuropsychologia, 44*(12), 2526-2532.

Rodrigues, P., Vasconcelos, O., Barreiros, J., Barbosa, R., & Trifilio, F. (2009). Functional asymmetry in a simple coincidence anticipation task: Effects of handedness. *European Journal of Sport Sciences,* 9, 2, 115-123.

Sainburg, R. L. (2002). Evidence for a dynamic-dominance hypothesis of handedness. *Exp Brain Res, 142*(2), 241-258.

Satz, P., & Green, M. F. (1999). Atypical handedness in schizophrenia: some methodological and theoretical issues. *Schizophr Bull, 25*(1), 63-78.

Searleman, A., & Porac, C. (2001). Lateral preference patterns as possible correlates of successfully switched left hand writing: data and a theory. *Laterality, 6*(4), 303-314.

Sicotte, N. L., Woods, R. P., & Mazziotta, J. C. (1999). Handedness in twins: a meta-analysis. *Laterality, 4*(3), 265-286.

Singh, M., & Bryden, M. P. (1994). The factor structure of handedness in India. *Int J Neurosci, 74*(1-4), 33-43.

Strang, J. (1991). Left-Handedness and Life Expectancy. *New England Journal of Medicine, 325*(14), 1041-1042.

Taylor, M. A., & Amir, N. (1995). Sinister psychotics. Left-handedness in schizophrenia and affective disorder. *J Nerv Ment Dis, 183*(1), 3-9.

Triggs, W. J., Calvanio, R., Macdonell, R. A., Cros, D., & Chiappa, K. H. (1994). Physiological motor asymmetry in human handedness: evidence from transcranial magnetic stimulation. *Brain Res, 636*(2), 270-276.

Uomini, N. T. (2009). The prehistory of handedness: archaeological data and comparative ethology. *J Hum Evol, 57*(4), 411-419.

Volkmann, J., Schnitzler, A., Witte, O. W., & Freund, H. (1998). Handedness and asymmetry of hand representation in human motor cortex. *J Neurophysiol, 79*(4), 2149-2154.

Vuoksimaa, E., Koskenvuo, M., Rose, R. J., & Kaprio, J. (2009). Origins of handedness: a nationwide study of 30,161 adults. *Neuropsychologia, 47*(5), 1294-1301.

Williams, C. S., Buss, K. A., & Eskenazi, B. (1992). Infant resuscitation is associated with an increased risk of left-handedness. *Am J Epidemiol, 136*(3), 277-286.

S. Akpinar
Nevşehir Hacı Bektaş Veli University, Faculty of Education, Department of Physical Education and Sport Education, 50300 Nevşehir, Turkey
e-mail: sakpinar@nevsehir.edu.tr