Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XII, ISSUE 2 Supplement 2012, Romania
The journal is indexed in: Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengace Learning

LATERALITY - DETERMINANT FACTORS AND INFLUENCES

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Abstract

Environmental factors or genetic instructions seem to be two processes that can cause variations in the upper and/or lower limb preference. Preferential use of the upper and/or lower limb in moderate or high (sport performance) intensity physical exercise can cause an unbalanced muscle behavior (especially in terms of force) between the right and left side of the body, which can have undesirable implications on normal development of the human body. In other words, asymmetrical sports specific biomechanics may predispose the subject to neuromuscular disbalances. Therefore, understanding laterality determining factors and influences may lead to a better knowledge of this phenomenon.

Key words: laterality, preference, dominance, right, left.

Introduction

From anatomically and functionally point of view, people present two identical external anatomical halves centrally merged. Even if the two external anatomical halves are identical, people give a greater preference to one of the body sides or to one of the upper and/or lower corresponding limbs (B. J. C. Perera, 2009). Fundamental basis of this perception is represented by the concept of laterality.

Laterality is defined as functional inequality of a body part as a consequence of the difference in development and distribution functions in the cerebral hemispheres. Therefore, functional weight of a pair limb or organ is called "laterality", and is manifested by the fact that humans execute certain activities with more pleasure, skill, efficiency, ease and speed, with one pair of limbs or organs, giving a systematic priority to it (K. Mekota, 1976).

Laterality is linked to a dominant cerebral hemisphere function that causes inequality of the body left and right halves. Sensory asymmetry phenomenon seems to be innate and is based on a certain functional organization of brain structures. Cerebral dominance is one of the most often used factors to explain laterality and especially to explain the hand dominance. It appears that hereditary and cultural mechanisms are indispensable, and work together in determining laterality.

In this study, laterality determining factors and influences are examined in detail, to a better understanding of this phenomenon.

Laterality reflection in the cerebral hemispheres

In right-handed adult subjects, left cortical motor area controls the right upper limb and in left-handed adult subjects, right cortical motor area controls the left upper limb. The cerebral hemisphere that controls language is called the dominant hemisphere. In the vast majority of people, language functions are processed in the left hemisphere. Brain lesions that adversely affect language are found in the hemisphere in about 95% of cases, as evidence of left brain dominance (D. E. Haines, 2008). About 90% of right-handed subjects have nerve centers that control speech located in the left hemisphere, and the remaining 10% have nerve centers that control speech located in the right hemisphere. Also, about 65% of left-handed subjects have nerve centers that control speech, located in the left hemisphere, 20% have nerve centers that control speech, located in the right hemisphere, and the remaining 15% have nerve centers that control speech, located in both cerebral hemispheres. 60% of ambidextrous subjects have nerve centers that control speech, located in the left hemisphere, 10% have nerve centers that control speech, located in the right hemisphere, and the remaining 30% have nerve centers that control speech, located in both cerebral hemispheres (C. R. Noback et al., 2005). D. E. Haines, (2008), speculates that almost all right handed subjects and about half of left handed subjects are left cerebral dominant. So, the right cerebral hemisphere, in most of general population, is the nondominant hemisphere.

Observations realized by autopsy have shown that larger and more numerous groups of nerve bundles connect both cerebral hemispheres in left-handed subjects, then right-handed subjects, suggesting that more nerve impulses are traveling between cerebral hemispheres in left-handed subjects.

Hand position during writing correlates with cerebral dominance. Subjects, who write by hand in a non-inverting position (normal), present cerebral dominance in opposition to preferential utilization of the upper limb. Thus, a large number of subjects with right upper limb preference present left cerebral dominance and only a small number of subjects with left upper limb preference present left cerebral dominance. Also, individuals who write by hand in an inverted position, have cerebral dominance in the same side as the upper limb preference. Thus, a large number of subjects with left upper limb preference present left cerebral dominance and a very small number of subjects with right upper limb preference present right cerebral dominance. Cerebral dominance cannot be determined in some subjects, by observations of hand writing position, probably because of the cerebral hemispheres interconnection (J. G. Creager, 1992). Subjects, which have the right part of the body dominant, have a higher

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Received 10.03.2012 / Accepted 12.08.2012

metabolic activity in the left hemisphere, and subjects, which have the left part of the body dominant, have a higher metabolic activity in the right hemisphere (R. C. Gur and M. Reivich, 1980). Also, R. C. Gur et al., (1982) showed that the direction and degree of hemispheric asymmetry of cerebral blood flow are influenced by gender and upper limb preferential use.

Factors influencing laterality

Genetic instructions appear to be identical for both parts of the body (right and left), differences appeared when decoding these instructions to muscles, nerves, blood distribution and other characteristics required for organs functions. The additional specific influence on human brain asymmetry is characterized by the presence of RS+ gene (Right Shift) to most people, which induces a typical cerebral specialization manifested by an advantageous functionality of the left hemisphere and a weaken functionality of the right hemisphere. The effect of this gene, in the physical asymmetry of the upper limb and brain, is expected to be cumulative. This gene does not lead directly to preferential use of upper limb, but is more likely to improve, at higher levels of skill, the functionality of the right side. However, the functional effect of RS+ gene presence is expected to be the lateralization of speech in the left hemisphere (M. Annett, 2006). Also, RS+ gene is present in approximately 80% of the population, in which are included the monozygotic and, also, dizygotic twins. However, approximately 18,5% of the population is expected to have a genotype RS-- and develop a cerebral specialization at random, and 8-10% of the population is expected to have an RS++ genotype (M. Annett, 2003).

Preferential use of the upper limb is important in genetic theories of asymmetry, because of the distinction between monozygotic twins, which are actually genetically identical, and dizygotic twins, who share on average 50% of genes. Thus, a study by A. Davis and M. Annett, (1994), found that the preferential use of left upper limb is significantly more pronounced in twins subjects (almost in the same proportion in monozygotic twin pairs and dizygotic twin pairs) (I.C. McManus, 1980; N. L. Sicotte et al., 1999; M. Annett, 2006), reported to single born subjects, in male subjects compared to female subjects (J. F. Orlebeke et al., 1996; M. Reiss and G. Reiss, 1997) and also in young subjects compared to adult subjects (A. N. Gilbert and C. J. Wysocki, 1992). In contrast, D. Gidu, (1998), in a study of 16 female subjects and 16 male subjects, aged between 9 and 12 years, showed that male subjects have a right preponderance stronger than female subjects. Also shown in the same study, there is no correlation between hand preference and muscle fatigue model installation.

A. Davis and M. Annett, (1994), found in a study of 30 000 subjects, aged between 18 and 80 years, that preference of left upper limb in single born subjects is about 7.1%, and in twin subjects is approximately 11,7%. Differences in upper limb preference are due to environment influences (J. F. Orlebeke et al., 1996; K. Tambs et al., 1987), because these differences are mainly attributed to disturbances occurring in the early development of the subjects. However, this does not directly involve the idea that, there is not a genetic influence in determining the preference in using the upper limb.

Preferential use of left upper limb is associated with neurological development problems, which includes learning disabilities (dyslexia), mental retardation, autism, schizophrenia (M. Cannon et al., 1995) and epilepsy (F. H. Previc, 1996). Many neurological development problems associated with preferential use of left upper limb are more common in male subjects.

Corresponding right hand thumb sucking was observed in approximately 90% of fetuses and corresponding left hand thumb sucking was observed in approximately 10% of fetuses in week 15 of intrauterine development. The same subjects, after 10-12 years of age (after birth), showed a remarkable correlation of hand preference with intrauterine hand preference behavior. From the 60 fetuses, which sucked the right hand thumb, only one has written with the left hand and from the 15 fetuses which sucked the left hand thumb, only 7 have written with the left hand. Male fetuses, which sucked the left hand thumb, tend to use preferentially the right hand in adolescence compared to female subjects (P. G. Hepper et al., 2005). P. G. Hepper, S. Shahidullah, R. White, (1991), have observed using ultrasound, that 92% of fetuses who sucked the thumb, tend to suck more often the thumb corresponding to the right hand, this value being very close to the value of the upper limb preferential use in general population (89% of adults write and throw with the right hand) (A. N. Gilbert and C. J. Wysocki, 1992). P. G. Hepper, G. R. McCartney, E. A. Shannon, (1998) have shown that fetuses, situated in week 10 of intrauterine development, have moved more often the right upper limb (85% of fetuses), then the left upper limb, and also, 75% of fetuses showed a preference for the right upper limb. Thus, the main implication of RS (Right Shift) theory is that, the mechanism that induces preferential change to the right is operating in very early stages of human development, even before the development of the cerebral cortex.

C. S. Williams, K. A. Buss, B. Eskenazi, (1992) have shown that births performed with complications (twins or triplets, which required resuscitation after birth) seem to increase the probability of preference in the use of left hand and leg. Also, low weight at birth is associated with an increased probability of left hand preferential use, due to intrauterine growth disturbances recorded in twins, which is valid only for the first born of twins pair (J. F. Orlebeke et al., 1996).

Genes responsible for the use of hand preference are sometimes transmitted to offspring (sons and daughters), and sometimes not, all of this offering the basic transmission of hand preference in family (N. L. Sicotte et al., 1999; J. F. Orlebeke et al., 1996). Fathers,

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with left hand preference do not affect the probability of left hand preference transmission to daughters. Also, the incidence of left hand preference in daughters, does not increase, even if the father has left hand preference (both parents have left hand preference). On the other hand, the sons seem more susceptible to have preference in using the left hand, if the fathers have preference in using left hand (J. F. Orlebeke et al., 1996).

Approximately 80% of adult subjects have right upper limb dominant, 10% left upper limb dominant (C. Hardyck and L. F. Petrinovich, 1977) and 10% are ambidextrous (C. R. Noback et al., 2005). Also, I. C. McManus, (1991), concluded that about 8% of people have left upper limb dominant. M. Reiss and G. Reiss, (1997), in a study of 506 male subjects and 430 female subjects, showed a higher preference in using the right upper limb in a percentage of 91% and a preference in using the right lower limb in a percentage of 74%; the incidence correlation of laterality between the two limbs (upper and lower), was 0.44.

C. Gabbard, (1992), in a study conducted on a group of children aged between 3 to 5 years old, showed that 52% of subjects had the right upper and lower limb dominant and 23% of subjects had the right upper limb dominant and lower limbs without dominance (mixed-use preference). I. Nachshon, D. Denno, S. Aurand, (1983) showed that approximately 80% of 7364 children (of different races and sexes) had preferences in use for the right upper and lower limbs. Also, no significant differences between races and sexes, was registered for the preferential use of right and left limbs. C. Gabbard, (1993) showed that, for subjects aged between 3 to 11 years old, the dominance of lower limb is not pronounced, and almost twice the number of subjects with not pronounced dominance of lower limb present mixed preferential use of the lower limbs. Studies on populations of adult subjects have shown that a higher proportion of subjects with right upper limb dominance present the same lower limb dominance, then subjects with left upper limb dominance, which also present left lower limb dominance.

C. Gabbard and M. Iteya, (1996) concluded, after reviewing 14 studies, that the percentage of children without lower limb dominance is substantially higher than the percentage of adult subjects without lower limbs dominance. The number of children without lower limb dominance is about two times higher than the number of children without upper limb dominance, fact found in adolescents and adults, but with a smaller difference. However, in the late adolescence, there is a significant shift to the right in dominance, followed by a relative stabilization of this behavior. Other studies have shown that adult subjects show a significant switch from the left dominance or no dominance of the lower limbs, to the right lower limb dominance (J. Bell and C. Gabbard, 2000), fact suggested by C. Porac, (1996), but for upper limbs. Also, the incidence of preferential use of left upper limb decreases, more or less linearly with age, in both sexes (A. N. Gilbert and C. J. Wysocki, 1992).

Sociocultural differences between countries or geographical regions further complicate the explication of data for the preferential use of upper or lower limbs. Thus, in Western cultures since the beginning of last century, the preferential use of left hand was considered undesirable and therefore the students who preferentially used the left hand were often forced to write with the right hand. With time, obligatory use of right hand has dropped dramatically, increasing the number of subjects who used the left hand preference, from about 3% in 1910 to 12% in subjects born after World War II. However, marked cultural differences remained on the preferential use of left hand; for example, the incidence of preferential use of left hand extends from about 2.5% in Mexico to about 12% in Canada (I. B. Perelle and L. Ehrman, 1994). Other studies showed a preferential use of left hand of 11.5% in Canada and England, 7.5% in UAE, 5.8% in India, 4% in Japan, 7.9% in Côte Ivory and 5.1% in Sudan. However, cultural differences in the incidence of left hand preferential use are not strong enough to justify such data. Studies on Asian population born in the west, shows the same levels of incidence in left hand preferential use, as the Asian population born in Asia. These facts strongly support the idea that subjects have preferential use of left hand or right hand, because of their genes which each possess (I. C. McManus, 2002).

Variations in preferential use of the upper and lower limbs, genetically determined, influenced by environment, influenced by cultural trends, influenced by development or influenced by combinations of these, remain highly controversial in the literature (K. N. Lalande et al., 1995).

The upper and lower limb dominance effect on muscle strength balance in sports

Dominance of the upper limb has a higher impact, than the lower limb dominance in the development of spine muscle strength, in sedentary people. It is well known that most complex and diverse movements are performed with the upper limbs, than lower limbs which mainly present symmetrical movements (except the movements which are made by playing a sport).

Thus, E. Andersson, L. Swärd, A. Thorstensson, (1988), found significant differences in maximum isometric strength production in movements of flexion, extension and lateral flexion between athletes (football players, wrestlers, tennis players and gymnasts) and sedentary subjects (all subjects were aged between 18 and 22 years old). Also, in the right and left lateral flexion movements, wrestlers and tennis players developed an isometric strength significantly higher in the non-dominant side of the trunk (represented also by the non-dominant upper limb). These differences present between athletes and sedentary subjects seem to be related to the specificity of sport and also due to long-term training systematically practiced.

It seems that tennis specific biomechanics predispose the player to back spine neuromuscular disbalances (significant differences between the right and left side of the lumbar extensor muscles), closely correlated with the dominant upper limb used in tennis game practice. These disbalances can be corrected by applying an exercise program for the lumbar muscles (E. Andersson et al., 1988; T. Renkawitz et al., 2008). Another aspect of handedness in tennis postulate the idea that 90% of the time left handers have to play against right handers and 10% of the time right handers have to play against left handers. Therefore, the left handers back-hand strokes are stronger because they have to face 90% of time to fore-hand strokes generated by right handers. Also, fencing is another sport where left handers show signifiant dominance against right handers.

It seems that athletes who systematically practice handball and track and field (triple jump) are likely to develop maximum isometric force disbalances of antagonistic muscles necessary to realise the movements in frontal (lateral flexion) and/or transverse (lateral rotation) plane at the level of the spine, due to preferential use of one of the upper and/or lower limb.

S. Parkin, A. V. Nowicky, O. M. Rutherford, A. H. McGregor, (2001), in a study of 19 rowers and 20 control subjects (almost identical in terms of age, body height and weight), have found that asymmetric myoelectrical activity observed between right spinal extensor muscle and left spinal extensor muscle, necessary to execute extension movement, significantly correlates with the part in which the rower is paddling. Although, the maximum isometric force exerted by trunk extensor and flexor muscles, is not different between control subjects and rowers, the myoelectric activity was significantly higher in rowers than control subjects.

Therefore, the subjects who practice sports whit asymmetrically movements will develop a higher strength of one side of the body or one upper and/or lower limb according with theirs preferential use of one of the upper and/or lower limb.

Conclusions

Variations in preferential use of the upper and lower limbs seem to be genetically determined, as a result of genes which each possess or seem to be determined by environmental factors. Further studies are necessary to assess the current outcome of this statement.

It seems that neuromuscular disbalances between right and left parts of the body are closely correlated with the dominant upper or lower limb used in sports practice. So, sports specific asymmetrical biomechanics predispose the player to neuromuscular disbalances.

References

ANDERSSON, E., SWÄRD, L., THORSTENSSON, A. 1988. *Trunk muscle strength in athletes.* Medicine and science in sport and exercise, 20 (6): 587-593.

ANNETT, M. 2003. *Cerebral asymmetry in twins: Predictions of the right shift theory*. Neuropsychologia, 41 (4): 469-479.

ANNETT, M. 2006. *The Right Shift Theory of Handedness and Brain Asymmetry in Evolution,* Development and Psychopathology. Cogniţie, Creier, Comportament (Cognition, Brain, Behavior), 10: 235-250.

BELL, J., GABBARD, C. 2000. *Foot preference changes through adulthood.* Laterality, 5 (1): 63-68.

CANNON, M., BYRNE, M., CASSIDY, B., LARKIN, C., HORGAN, R., SHEPPARD, N. P., O'CALLAGHAN, E., 1995. *Prevalence and correlates of mixed-handedness in schizophrenia.* Psychiatry Research, 59 (1-2): 119-125.

CREAGER, J. G., 1992. *Human anatomy and physiology,* 2nd ed., Wm. C. Brown Publishers, Dubuque, IA: 333-335.

DAVIS, A., ANNETT, M. 1994. *Handedness as a function of twinning, age and sex,* Cortex, 30 (1): 105-111.

GABBARD, C., 1992. *Associations between hand and foot preference in 3- to 5-year-olds.* Cortex, 28 (3): 497-502.

GABBARD, C., 1993. *Foot laterality during childhood: a review.* The international journal of neuroscience, 72 (3-4): 175-182.

GABBARD, C., ITEYA, M., 1996. *Foot laterality in children, adolescents, and adults.* Laterality, 1 (3): 199-205.

GIDU, D., 1998. *Preferinţa manuală, forţa maximală şi modelul instalării oboselii în testarea flexorilor palmari, la începătorii în handbal.* Sesiunea ştiinţifică internaţională Olimpism şi ştiinţa sportului (II), 30-31 mai 1998, Bacău: 23-36.

GILBERT, A. N., WYSOCKI, C. J., 1992. *Hand preference and age in the United States.* Neuropsychologia, 30 (7): 601-608.

GUR, R. C., GUR R. E., OBRIST, W. D., HUNGERBUHLER, J. P., YOUNKIN, D., ROSEN A. D., SKOLNICK, B. E., REIVICH, M., 1982, *Sex and handedness differences in cerebral blood flow during rest and cognitive activity.* Science, 217 (4560): 659-661.

GUR, R. C., REIVICH, M., 1980. *Cognitive task effects on hemispheric blood flow in humans: evidence for individual differences in hemispheric activation.* Brain and language, 9 (1): 78-92.

HAINES, D. E., 2005. *Fundamental Neuroscience for Basic and Clinical Applications.* 3rd ed., Churchill Livingstone/Elsevier, Philadelphia, PA.

HARDYCK, C., PETRINOVICH, L. F., 1977. *Left-Handedness.* Psychological Bulletin (American Psychological Association), 84 (3): 385-404.

HEPPER, P. G., MCCARTNEY, G. R., SHANNON, E. A.,1998. *Lateralised behaviour in first trimester human fetuses.* Neuropsychologia, 36 (6): 531-534.

HEPPER, P. G., SHAHIDULLAH, S., WHITE, R., 1991. *Handedness in the human fetus.* Neuropsychologia, 29 (11): 1107-1111.

HEPPER, P. G., WELLS, D. L., LYNCH, C., 2005. *Prenatal thumb sucking is related to postnatal handedness.* Neuropsychologia, 43 (3): 313-315.

LALAND, K. N., KUMM, J., VAN HORN, J. D., FELDMAN, M. W.,1995. *A gene-culture model of human handedness*, Behavior Genetics, 25 (5): 433-445.

McMANUS, I. C.,1980. *Handedness in twins: a critical review.* Neuropsychologia, 18 (3): 347-355.

McMANUS, I. C.,2002. *Right hand, left hand: The origins of asymmetry in brains, bodies, atoms and cultures.* Weidenfeld & Nicolson, London.

McMANUS, I. C., 1991. *The inheritance of left-handedness.* Ciba Foundation Symposium, 162: 251-267.

MEKOTA, K., 1976. *Lateralitatea motrică.* Telesna vycova mladeze, 5, 1975, Educaţie fizică în şcoală, vol. XXXIII, Ed. C.N.E.F.S., Bucureşti: 33-42.

NACHSHON, I., DENNO, D., AURAND, S., 1983. *Lateral preferences of hand, eye and foot: relation to cerebral dominance.* The international journal of neuroscience, 18 (1-2): 1-9.

NOBACK, C. R., STROMINGER, N. L., DEMAREST, R. J., RUGGIERO, D. A., 2005. *The human nervous system.* 6th ed., Humana Press, Totowa, N.J..

ORLEBEKE, J. F., KNOL, D. L., KOOPMANS, J. R., BOOMSMA, D. I., BLEKER, O. P., 1996. *Left-handedness in twins - genes or environment.* Cortex, 32 (3): 479-490.

PARKIN, S., NOWICKY, A. V., RUTHERFORD, O. M., MCGREGOR A. H., 2001. Do oarsmen have asymmetries in the strength of their back and leg muscles?. *Journal of sports sciences, 19 (7): 521-526.*

PERELLE, I. B., EHRMAN, L., 1994. *An international study of human handedness: The data.* Behavior Genetics, 24: 217-227.

PERERA, B. J. C., 2009. *Some facets of laterality in Sri Lankan children.* Sri Lanka Journal of Child Health, 38: 4-20.

PORAC, C., 1996. *Attempts to switch the writing hand: relationships to age and side of hand preference.* Laterality, 1 (1): 35-44.

PREVIC F. H.,1996. *Nonright-handedness, central nervous system and related pathology, and its lateralization: A reformulation and synthesis.* Developmental Neuropsychology, 12 (3): 443-515.

REISS, M., REISS, G., 1997. *Lateral preferences in a German population.* Perceptual and Motor Skills, 85 (2): 569-574.

RENKAWITZ T., LINHARDT O., GRIFKA J. 2008. *Electric efficiency of the erector spinae in high performance amateur tennis players*. The journal of sports medicine and physical fitness, 48 (3): 409-416.

SICOTTE, N. L., WOODS, R. P., MAZZIOTTA, J. C., 1999. *Handedness in twins: a meta-analysis.* Laterality, 4 (3): 265-286.

TAMBS, K., MAGNUS, P., BERG, K., 1987. *Left-handedness in twin families: Support of an environmental hypothesis.* Perceptual and Motor Skills, 64 (1): 155-170.

WILLIAMS, C. S., BUSS, K. A., ESKENAZI, B. 1992. *Infant resuscitation is associated with an increased risk of left-handedness.* American Journal of Epidemiology, 136 (3): 277-286.