

# Incidence and Gender Differences for Handedness among Greek Adolescents and Its Association with Familial History and Brain Injury

F. Vlachos<sup>1,\*</sup>, E. Avramidis<sup>1</sup>, G. Dedousis<sup>2</sup>, E. Katsigianni<sup>1</sup>, I. Ntalla<sup>2</sup>, M. Giannakopoulou<sup>3</sup>, M. Chalmp<sup>1</sup>

<sup>1</sup>Special Education Department, University of Thessaly, Volos, Greece

<sup>2</sup>Department of Nutrition and Dietetics, Harokopio University, Athens, Greece

<sup>3</sup>Department of Nursing, National and Kapodistrian University of Athens, Athens, Greece

\*Corresponding author: [fvlachos@uth.gr](mailto:fvlachos@uth.gr)

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**Abstract** Handedness is marked by the preference of one hand over another for fine motor tasks, especially writing. Usually, only one hand is considered dominant; however, there are individuals who exhibit the ability to use both hands equally (mixed-handers). The aim of this study was to identify the incidence for handedness in a sample of Greek adolescents and examine possible gender differences in handedness among these adolescents and their siblings. 634 secondary school students (Mean age 13.38, SD = 1.47) who attended mainstream public schools participated in this study. All students completed the Edinburgh Handedness Inventory (EHI). Students were divided in three groups, namely right-handers (an EHI +50 to +100), mixed-handers (an EHI -49 to +49) and left-handers (an EHI -100 to -50). This process resulted in the classification of 544 adolescents (85.8%) as right-handed, 46 adolescents (7.3%) as left-handed and 44 adolescents (6.9%) as non-lateralized (ambidextrous). Contrary to previous research, the statistical analysis conducted did not reveal any significant differences in the prevalence of handedness between genders. Nevertheless, our data suggest that men might be more prone to ambidexterity. Similarly, although some interesting trends were observed in our data, the statistical analyses performed did not confirm the familial effect upon handedness and the pathological left-handedness hypotheses. The paper concludes with underlining the significance of the evidence presented here and discusses the inconclusive findings often reported in the literature concerning the association of handedness with family history and brain injury.

**Keywords:** handedness, incidence, gender, familial effect, brain injury

## 1. Introduction

Handedness is the best-known and most studied human asymmetry, and it can be defined as “the individual’s preference to use one hand predominately for unimanual tasks and/or the ability to perform these tasks more efficiently with one hand” [1]. Usually, only one hand is considered dominant; however, there are individuals who exhibit the ability to use both hands equally (mixed-handers).

A variety of studies suggest that 70-90% of the world population is right-handed, rather than left-handed or any other form of handedness [2]. However, there has been considerable debate about the incidence of left-handedness, with studies reporting figures ranging from 1.6% [3] to 32.2% [4], with the most common figures being in the region of 10% [5,6]. Interestingly, in an unpublished, large-scale systematic review including 1.8 million participants, the incidence of left-handedness lay between 7.52% (in studies adopting the most stringent criterion of extreme left-handedness) and 17.42% (in studies adopting the most lenient criterion of non-right handedness) [7]. In a relevant study in Greece [8] involving 6503 students

aged 9-18 years, the mean frequency of left-handedness was found to be 2.2%. In another study [9] where 1971 elementary school children were assessed, 91.78% were classified as right-handers, 7.35% as left-handers and 0.86% as bi-manuals. One possible reason for the apparently contradictory findings in these studies may be the different ways of identifying handedness.

It is also widely reported that a significant male over-representation exists among left-handers. A recent meta-analysis of 144 studies [10] demonstrated that the sex difference in handedness is both significant and robust, indicating that the overall best estimate for the male to female odds ratio was 1.23. Similarly, in an earlier Greek study [9], the comparison between the sexes revealed higher proportions of left-handed boys than girls (8.26% and 6.41% respectively); nevertheless, this difference was not statistically significant. It must be mentioned however that although the sex differences in handedness are widely reported this finding is not universal [10].

Various theories have been put forward to explain the origin of handedness, and its implications for cognitive development and learning. Generally, there are both genetic and environmental theories. In our days, it is commonly accepted that human handedness is predominantly determined by gene(s); nevertheless, it is

also recognized that environmental influences clearly play a role in the handedness phenotype [6]. Handedness runs in families and as a result is thought to be partly hereditary. Left-handedness is more common if one parent is left-handed and even more common if both parents are left-handed [11,12]. Children of two left-handed parents might have a much higher chance of being left-handed (26.1%) than do the children of two right-handed parents (9.5%), yet their handedness is hardly guaranteed [12]. However, it has been argued [13] that studies of family resemblance in handedness show both similarities and discrepancies in outcomes between them.

The emergence of handedness has been explained by physiological and pathological models. According to the theoretical account of pathological left-handedness syndrome, a subgroup of left-handers suffers from a condition that involves an early injury. This syndrome is believed to be caused by a hemispheric lesion that is predominantly left-sided (or bilateral asymmetric), which onsets before the age of 6, and which encroaches upon the critical speech zones of the frontotemporal/frontoparietal cortex [14]. Accordingly, left-handers include a proportion of potentially pathological people who might present impaired performance in various cognitive tasks which presumably stem from the left hemispheric damage. Thus, any brain injury in very early life, before, during and after birth affects the lateralization process causing atypical handedness (left or mixed handedness), although mechanisms are not fully understood [14]. However, a recent study [15] did not find any evidence that left-handed children have a significantly higher probability of experiencing an injury that requires medical attention.

In sum, given that there is the considerable variation between studies on the incidence and the gender ratio in handedness, as well as controversy regarding the association of handedness with familiar history and brain injury, more research is needed. This might be due to lack of attention and accuracy of determining and classifying handedness. Moreover, the criteria used vary from one study to another. As a result, some studies consider handedness as a bimodal phenomenon and omit mixed-handed participants.

This study used a reliable and well-validated instrument to evaluate handedness aiming: (a) to identify the incidence of handedness in a sample of Greek adolescents; (b) to examine possible gender differences in handedness among these adolescents; (c) to assess the familial effect upon handedness, examining if left-handed parents are more likely to have left-handed children and (d) to examine the hypothesis that left- or mixed-handedness could be the result of brain pathology [13].

## 2. Method

### 2.1. Participants

Multistage cluster sampling was employed with a view to drawing a nationally representative sample. The process entailed three stages: the sampling of two geographical regions, the sampling of two counties within the selected regions, and the sampling of twelve secondary schools within the selected counties. This final stage also entailed stratification in terms of school location; that is, we

randomly chose four urban (located in cities with more than 10,000 inhabitants), four semi-urban (places of 2,500 to 10,000 inhabitants), and four rural schools (areas with less than 2,500 inhabitants). Following this clustering strategy, questionnaires were administered to seventy randomly selected students in each of the twelve selected schools (total sample of 840 students). Completed questionnaires were returned by 634 secondary school students (Mean age 13.38, SD = 1.47) representing a 75% return rate. All participants spoke Greek as their first language, and did not have a history of major medical illness, psychiatric illness, or significant visual or auditory impairments according to the medical reports of their schools.

### 2.2. Material & Procedure

Handedness was defined through administering the Edinburgh Handedness Inventory (EHI) [16]; a reliable and well-validated instrument. Numerous studies have confirmed the objectivity and reliability of EHI with other handedness questionnaires [17,18,19,20]. Test-Retest reliability of the EHI as measured by the Pearson  $r$ , Kendall  $\tau$ , and Spearman  $r_s$ , range from 0.95 to 0.98 [19]. The medium to high correlations of the EHI with other behavioral measures of handedness (for example the Purdue Pegboard test, a test of manual dexterity) demonstrate the high concurrent validity of the test [21,22,23]. According to the Citation Index, the EHI has been the most widely used inventory in the literature. The instrument is comprised of 10 items pertaining to hand-preference in writing, drawing, throwing a ball, use of scissors, use of toothbrush, use of knife (without fork), use of spoon, use of broom (upper hand), striking a match, and opening a box. Based on the participants' responses to the above items, we calculated a Laterality Quotient [LQ = (Right - Left)/(Right + Left) × 100] for each participant, which resulted in a score ranging from -100 to +100, where -100 indicated pure left-handedness and +100 indicated pure right-handedness.

Additionally, a second questionnaire was administered to each participant, which comprised of questions about their parents' history of handedness as well as their history of a brain injury. While the question about the parents' history of handedness was a straightforward one, eliciting information about the students' history of a brain injury required particular care. Participants were classified as having experienced a brain injury if they responded "once" or "more than once" to the question "have you ever had a brain injury that required medical attention"? The validity of the students' accounts was confirmed through contacting independently the students' parents to confirm their handedness; and through requesting supporting medical evidence from those students (N=80) who had reported a history of brain injury. Further examination of these medical records revealed that all these students had experienced a left hemispheric injury of a mild to moderate nature. In line with previous studies [24,25] a mild to moderate brain injury was defined in this study as any blow to the head forcing one to stop whatever one was doing, and being serious enough to require medical attention. In this respect, this subgroup of participants could be viewed as a homogenous sample.

### 3. Results

#### 3.1. Incidence of Handedness in a Sample of Greek Adolescents

According to their Laterality Quotients, we classified respondents in three groups, whereby those students who scored between +50 and +100 were considered as right-handers (an EHI score +50 to +100), those students who scored between -49 and +49 were considered as mixed-handers, and those who scored between -50 and -100 were considered as left-handers. This process resulted in the classification of 544 adolescents as right-handed (85.8%), 46 adolescents as left-handed (7.3%) and 44 adolescents as non-lateralized i.e. mixed-handed (6.9%). Figure 1 shows the classification of the participating adolescents in the three handedness groups.

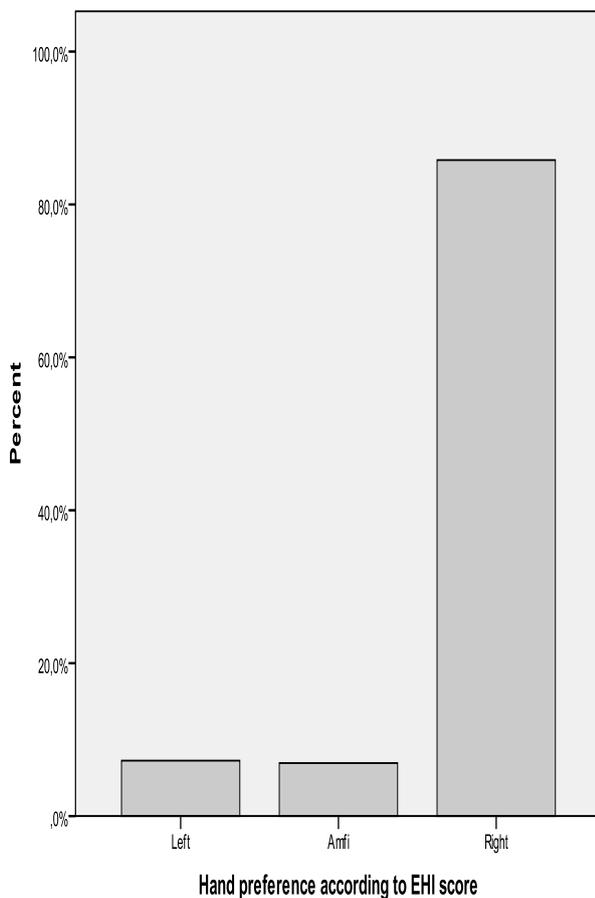


Figure 1. Percentages of adolescents in the three handedness groups

#### 3.2. Gender Differences in Handedness among these Adolescents

Next, the analysis examined whether there was any association between the respondents' gender and their handedness. The comparison between the sexes revealed higher proportions of left-handed girls than boys (8.4% and 5.5% respectively), while the reverse direction was found between mixed-handed participants (6.3% girls and 9.2% boys). Between right-handers 85.3% were girls and 86.6% were boys. The chi-squared analysis performed did not reveal a statistically significant difference in the prevalence of handedness between genders ( $\chi^2 = 2.44$ ,  $p = .29$ ).

The gender distribution of the participants in the three handedness groups is presented in Figure 2:

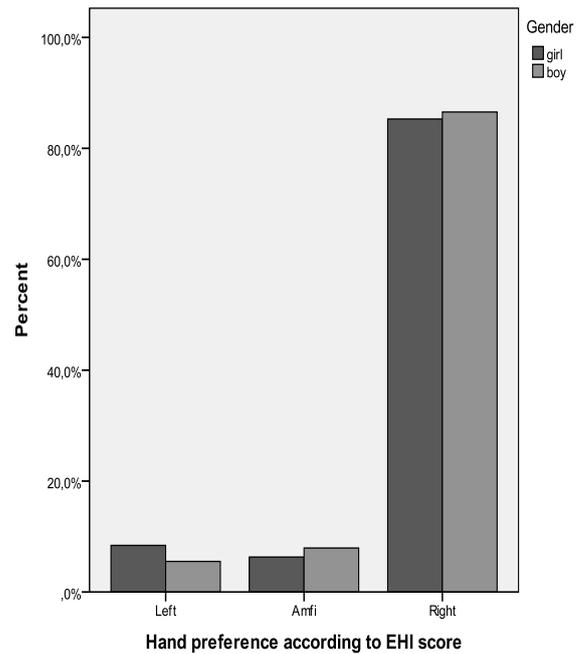


Figure 2. Percentages of boys and girls in the three handedness groups

#### 3.3. The Familial Effect upon Handedness

Next, the analysis examined the familial effect upon handedness, that is, whether left-handed parents are more likely to have left-handed children. Although 18.2% of the identified left-handed students had a left-handed parent, as opposed to 12.8% of right-handed students (see Table 1), this difference was not statistically significant ( $\chi^2 = 2.71$ ,  $p = .26$ ).

Table 1. Hand preference of adolescents with and without a left-handed parent

	Hand preference		
	Left-handed	Mixed-handed	Right-handed
No Parent being left-handed	36 (78.3%)	39 (92.8%)	483 (88.8%)
Parent being left-handed	10 (21.7%)	3 (7.2%)	61 (11.2%)
Total	46 (100%)	42 (100%)	544 (100%)

#### 3.4. The Brain Pathology Hypothesis

Finally, the analysis tested the brain pathology hypothesis, whereby left- or mixed handedness could be the result of brain pathology. Although considerably different percentages of the three handedness groups reported an early brain injury (8.7% of the identified left-handed students, 20.9% of the mixed-handed and 12.5% of the right-handed students – see Table 2), the analysis did not reveal a significant association between head injury and handedness ( $\chi^2 = 4.16$ ,  $p = .12$ ).

Table 2. Hand preference of adolescents with and without brain injury

	Hand preference		
	Left-handed	Mixed-handed	Right-handed
No brain injury	42 (91.3%)	34 (70.1%)	472 (87.5%)
With brain injury	4 (8.7%)	9 (20.9%)	67 (12.5%)
Total	46 (100%)	43 (100%)	539 (100%)

## 4. Discussion

Our results showed that the incidence of left-handedness in a sample of Greek adolescents (7.3%), as well as the incidence of non-right-handedness (14.2%) are consistent to the data from other countries [7], [12]. The increased incidence of left-handedness in our study, contrary to an earlier study in Greece [8] could be attributed to the pressure exerted from the parents of left-handed children during the past decades to change the preferred hand for writing [9], which is no longer the case today.

With regard to sex differences in handedness, the data from this study do not lend support to the robust gender differences widely reported in the literature about the prevalence of left-handedness. Nevertheless, our data suggest the men are more prone to ambidexterity (mixed-handedness) compared to women, a finding also reported in a recent meta-analysis [10]. Additionally, the same meta-analysis concluded that the magnitude of the difference between sexes was significantly moderated by the way in which handedness was assessed (by writing hand or by other means).

Likewise, although our findings showed that children of a left-handed parent had a slightly higher chance of being left-handed than do the children of right-handed parents, this difference was not significant, indicating that a strong familial effect upon handedness does not exist. Our results, therefore, do not confirm previous studies reporting significantly higher incidence of left-handedness in offspring of left-handed parents [11,12,13]. As already mentioned, a possible reason for this discrepancy is the way handedness was assessed. In our study we used a reliable and well-validated handedness questionnaire, while in the other studies the criterion of handedness in both parents and offsprings was the hand used for writing. However, this criterion alone is not enough to distinguish clear hand preference groups. For that matter, other researchers [26] concluded that a contradiction in the literature regarding the association of handedness with other factors stem largely from different ways hand preference has been defined. Another factor that could explain the discrepancy is the age of the participants. We selected data from secondary school children, while in the other studies respondents were undergraduate students. It is worth noting, however, that the data of our study are in accordance with that of a recent international collaborative study of genetic influences on handedness [27] in which additive genetic effects accounted for about a quarter of the variance with the remainder accounted for by non-shared environmental influences. More specifically, researchers after analyzing a large sample of twin and family data for hand preference concluded that the familial aggregation for hand preference was found to be consistent with additive genetic effects, which accounted for about a quarter of the variation in the trait [27].

Finally, based on the neuropathological theory [14] we hypothesized that more left-handed and mixed-handed students than right-handed ones would have an early injury to the left hemisphere of the brain. Types of mild to moderate early brain injury in this study included cases of students who had experienced accidents or falls, the severity of which was such that medical attention was necessary. The data in this study do not offer empirical

support for the above mentioned neuropathological theory. Although 1 out of 5 mixed-handed and more than 1 out of 4 non-right-handed (mixed-handed plus left-handed) adolescents reported an early brain injury, our study did not detect a significant association between head injury and handedness.

Possibly, the sample size was not large enough to identify a statistically significant handedness effect. Therefore, a replication of the study with a larger sample size may be worthwhile. However, this finding is in accordance with recent suggestions that revisited hand preference as a marker for early life pathology [28]. More specifically, although, originally the term pathological left-handedness was reserved for hypothesized instances where cerebral lateralization was hampered by brain damage in very early life, recent findings [28] suggest that the term 'pathological' for left-handedness can be explained by other noxious causes, and that occurs irrespective of constitutional lateralization preference.

## 5. Conclusion

In summary, our data offer some insight concerning the relationships of handedness with family history and brain injury, advancing knowledge of these associations. From these data we take the view that for most associations, as well as for causes of left-handedness, there are yet unknown detailed underlying processes. We conclude that contradictions in the literature as to whether or not these factors are linked to handedness stem largely from different definitions and assessments of hand preference. However, as indicated in a recent review [29] the examination of handedness from an epidemiological standpoint such as the study reported here can provide valuable insight into cerebral lateralization. The results of this study should, therefore, trigger further research into the important question whether handedness is solely influenced by genes or whether there may also be environmental influences. Finally, researchers would do well in future to employ larger samples of participants and exercise care in their classification of handedness in order to reach robust conclusions.

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