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A brief study on the training pattern of sword fencing using motion capture techniques

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Abstract
This paper reports the consequences of an analysis that meant to contemplate move preparing in fencing. Fencers from the exploratory gathering went through six-week move preparing while those from the benchmark group went through ordinary fencing preparing. The fencers' presentation was examined threefold: before the trial preparing (pre-test), following it (post-test), and a month after it (maintenance test). Utilizing a gadget that mimics fencing moves and dissects the exactness of such execution, members finished, with two hands, three tests identified with straight push precision. While no distinctions close by grasp strength was seen between the two gatherings across the three tests, critical contrasts happened regarding their exhibition on the gadget. The gatherings didn't contrast in the pre-tests and the maintenance tests. Be that as it may, the fencers from the test bunch commonly performed preferred in post-tests over pre-tests. These outcomes show that respective exchange can be viable in foil fencing preparing, in spite of the fact that its constructive outcomes are present moment. To be compelling, move preparing should be utilized as an ordinary preparing apparatus.

Keywords: Bilateral transfer, fencing training, intermanual transfer, inter hemispheric transfer

Introduction
Preparing strategies dependent on reciprocal exchange are primarily utilized in one-sided (uneven) sports [1, 2]. Rosy and Carson [3] showed that actual preparing with one arm improves execution with the inverse (undeveloped) arm. This wonder is called intermanual move [3]. Comparative impacts have additionally been appeared in numerous other engine undertakings [4–12].

Intermanual move was recommended to result from plastic changes in the mind, which happen when new explicit neural organizations that control the truly prepared effector are shaped [13-15]. Inter hemispheric collaborations are regularly called inter limb associations [10, 12], intermanual connections [16, 17], contralateral co-operations [18, 19], and two-sided move [20]; from this time forward, we will utilize the term two-sided move. Different parts of engine control are lopsidedly circulated in the two sides of the equator of the mind [21, 22]. The left half of the globe [23] is answerable for unobtrusive and simultaneous developments that require successive and dynamic engine control while the correct side of the equator for unpredictable and instinctive developments, in this way having some expertise in visual and spatial movement control [24].
The above connections concur with the dynamic strength theory of handedness by Sainburg [25]. It expects that the predominant framework has some expertise in controlling powerful qualities while the non-prevailing one controls the spatial attributes of this development. The structures associating the sides of the equator-most importantly, the corpus callosum, additionally alluded to as the callosal commissure-influence the age and adequacy of individual human developments. The corpus callosum is the mind's biggest white tissue structure, answerable for inter hemispheric relations [26]. Mind imaging research recommends joins between the parietal and frontal flaps of the cerebrum's left side of the equator and the portrayal of aptitudes identified with the utilization of apparatuses and different items (transitive activities) [27].
To comprehend why preparing one appendage achieves the upgrades in the exhibition of the inverse (undeveloped) appendage,

cross-schooling marvel can help. Bronzed and Carson [3] indicated that the one-sided execution of a development task offered ascend to a two-sided increment in corticospinal volatility. During one-sided practice, such disseminated action (the cross initiation) prompts synchronous transformations in neural circuits that undertaking to the muscles of the undeveloped appendage, consequently encouraging ensuing execution of the assignment. As Ruddy and Carson [3] clarified, "on the other hand, reciprocal access models involve that engine engrams shaped during one-sided practice, may consequently be used respectively-that is, by the neural hardware that comprises the control communities for developments of the two appendages."

Engine learning in games can be founded on exchange preparing proposed by Starosta [28]. It utilizes a two-path stream of nerve driving forces between the sides of the equator. Speculations about expertise move showed up significantly sooner, notwithstanding. Models are Thorndike's exchange of training [29] and different hypotheses about the exchange and speculation of scholarly engine abilities to undeveloped aptitudes, just as Schmidt's mapping hypothesis of discrete engine expertise learning [30]. This blueprint expects that each educated engine expertise builds up the entire pattern, not only one specific connection between a boundary and its outcome. Fencing is a topsy-turvy sport-the weapon is held in one hand as it were. Consequently fencers are probably going to have practical deviation of the body, which can influence their fencing execution [31–33].

To improve execution, subsequently this unevenness may be considered in preparing. From one perspective, utilizing the non-prevailing arm influences neither one of the reactions time (RT) nor decision response time (CRT) [34]. Then again, tests for the non-prevailing arm went before by tests for the predominant arm brought about the decrease of RT and CRT, a cycle probably dependent on tactile preparing systems. As indicated by the engine program hypothesis of Schmidt and Wrisberg [35], very much learned engine propensities coded in the engine regions of the cerebral cortex can be adequately performed on both right and left sides. This marvel should be considered regarding the synaptic pliancy of the focal sensory system, which permits one to adequately learn new development structures and eliminate terrible engine propensities. Brought into preparing by methods for appropriate exchange preparing, the wonder may accordingly help improve fencing strategies and execution. It would do as such by influencing the nature of new engine propensities or improving those all around obtained. Also, restricting activities increment the strength and length of neural organizations, consequently advancing better engine coordination by diminishing the bioelectric strain of the initiated muscles [36].

The creators concentrated just transient impacts, following finishing a six-week move preparing. As far as we could possibly know, this has been the lone investigation on exchange preparing in fencing. Motivated by its outcomes, the current examination contemplates move preparing in more established foilists (age 14–20 years), as far as their exactness of straight push, the principle activity in foil fencing. Dissimilar to Witkowski *et al.* [41], this examination will dissect both present moment (i.e., following finishing the preparation) and longer-term (after a month) impacts of move preparing in foil fencing. This work hence plans to consider the adequacy and solidness of move preparing in foil fencing.

2. Materials and Methods

2.1. Participants

The gathering contemplated comprised of 32 foilists matured 14–20, the two men (n = 16) and ladies (n = 16), all being in any event transitional level fencers. The members were arbitrarily partitioned into two gatherings: (A) exploratory (n = 16) and (B) control (n = 16). The randomization was adjusted for sex and execution level: Four members from every associate gathering (i.e., junior ladies, cadet ladies, junior men, and cadet men) were arbitrarily allocated to the trial and control gatherings. Thus, both the trial gathering and the benchmark group included four cadet ladies, four junior ladies, four cadet men, and four cadet men, giving 16 members for every gathering and 32 members inside and out. The members were picked in order to speak to comparative fencing aptitudes, so neither age nor classification ought to have influenced the outcomes. All members were solid and post-pubescence.

The test bunch went through a six-week specific exchange preparing program (depicted beneath) while the benchmark group went through conventional fencing preparing. To survey the adequacy of the exchange preparing, straight push-a fundamental fencing method-was utilized with three variations. The straight pushed ability had been dominated by all participants. All the members announced right-handedness during trainings and sessions, which was affirmed with the Edinburgh Questionnaire [42] and its alteration [43].

The examination was led as per the moral norms of the Declaration of Helsinki (Ethical Principles for Research Involving Human Subjects). All the members were educated about the reason for the investigation and consented to partake on an intentional premise. The investigation was endorsed by the Research Ethics Committee of the Karol Marcinkowski University of Medical Science.

2.2. Intervention

The experiment aimed to compare the accuracy of hits before and after the specialized training and to assess the durability of its effects [44]. For each participant, hit accuracy and handgrip strength were assessed at each test session (Figure 1).

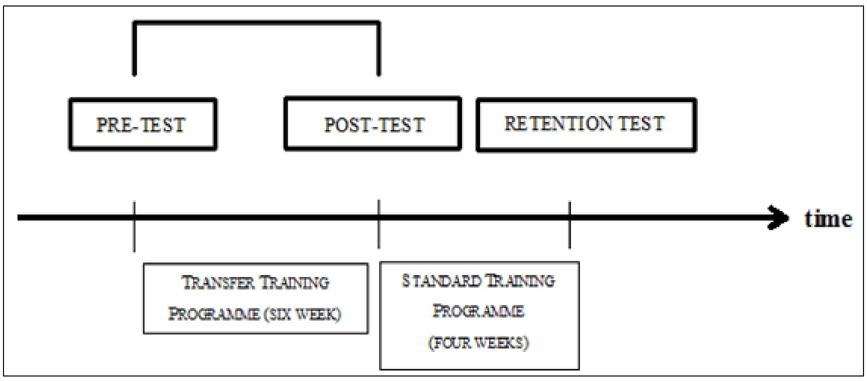

Fig 1: The timeline of the experiment

The specialized training program was implemented in the experimental group for six weeks, 30 min a day. It started off with two weeks of whole-body coordination activities involving both sides of the body; the activities used regular size balls of various textures and weights, a small size tennis ball, and a floor ladder. Each exercise was practiced three times on the non-dominant side and once on the dominant side. These activities were followed by two weeks of eye-to-hand and eye-to-foot coordination exercises with the additional equipment: fencing foils (appropriate for the non-dominant hand) and the Favero EFT-1 electronic fencing target (Favero Eletronics Srl, Arcade, Treviso, Italy). During the final two weeks, the fencers practiced lunges, parries, and other fencing techniques with the non-dominant side, with proper footwork, and repeated the activities practiced earlier, again for both sides with the three-to-one ratio. More details of the program can be found in Witkowski *et al.* [41].

2.3. Measurements
2.3.1. Hand grip strength test
Grip strength of each hand was measured with a hand dynamometer (TAKEI 5401, P & a Medical Ltd. Chorley, UK). Each participant made two contractions per hand, changing the hand in the subsequent trials. The wrist was an extension of the forearm and continued from it in a straight line. During the test, the tested hand could not touch any other part of the body. A better measurement was used in the analyses. Hand strength was measured with a precision of up to 0.1 kg.

2.3.2. Measuring the accuracy of hits
The precision of hits was surveyed utilizing the Favero EFT-1 electronic fencing objective (Favero Electronics Srl, Arcade (Treviso), Italy; Figure 2). The gadget has five focuses on, each furnished with a LED light. Two targets are put at a stature of around 90 cm over the ground, and the other two at around 130 cm over the ground. The objectives are separated 30 cm separated. The fifth objective is in the focal point of the gadget, at the convergence of the diagonals. The exactness of hits and season of finishing the test were estimated utilizing three unique tests conventions. In each test, the members intended to hit red targets (which arbitrarily lit up) with the tip of the foil (the catch). This methodology made it conceivable to decisively decide the precision of straight push in every convention.

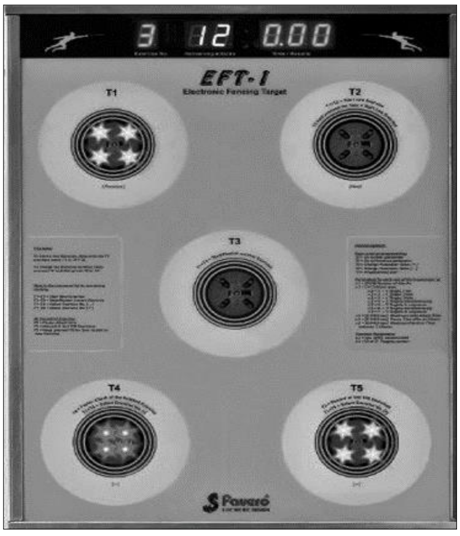

Fig 2: FAVERO: Electronic fencing target, EFT-1 (FAVERO Electronics SRL arcade (TV)-arcade, Italy).

The test protocols are described below:

a. In test 5, a fencer hits two randomly occurring targets that light up in ten cycles. A cycle consists of two hits: the first target lights up, and when it is hit, a second one lights. The fencer aims to complete the ten cycles in the shortest time. The test measures the accuracy of the hits and the time of completing each cycle. For the analyses, the mean time for the ten cycles was used, with a precision of 0.01 s. At the beginning of the task, the fencers took the en grade position at a distance suitable for a straight thrust. The tests were performed with both the dominant and the non-dominant hand.
b. In test 7, the fencer hits three targets that light up one by one in ten cycles. Again, the fencer aims to complete ten cycles in the shortest time.
c. In test 9, the fencer hits three targets that light up simultaneously, in three cycles. The test enables one to measure the accuracy of hitting three targets in the shortest possible time, a task requiring the fencer to take a proper perception strategy.

Similar methodology, based on measuring the accuracy of hits, has been used in other studies [33, 41, 45].

2.4. Statistical analysis
Two-way analysis of variance (ANOVA) was used, with one between-subject factor, called group (the experimental and the control groups), and one within-subject factor, called phase (repeated measurements in the three periods: before the experiment-the pre-test; right after the experiment-the post-test; and four weeks after the experiment-the retest). The group-by-phase interaction was analyzed. If the interaction was significant for a particular variable, the Bonferroni test was used for post-hoc analyses. When the sphericity assumption was violated, the Greenhouse-Geisser correction was applied. Statistica 13.1 software (Texas, TX, USA) was used for the analyses.

3. Results
3.1. Testing the accuracy of hits
The gathering by-stage collaboration impact was critical for the prevailing (right) hand for tests 5 and 7. The fencers from the exploratory gathering required a more limited interim to finish the post-test than the pre-test, and a more extended interim to finish the retest than the post-test. They finished the pre-test and the retest in comparable interims. For test 7, the fencers from the exploratory gathering finished their post-test in a more limited interim than those from the benchmark group. For tests 5, 7, and 9, the gathering by-stage communication impact was additionally critical for the non-prevailing (left) hand. The fencers from the exploratory gathering required a more limited interim to finish the post-test than the pre-test. A mean fulfillment season of the retest was longer than that of the post-test. Mean occasions of finishing the pre-test and the retest; nonetheless, didn't vary. The fencers in the test ground required a more limited interim to finish the post-test than the fencers in the benchmark group. The fencers in the benchmark group generally finished their pre-tests, post-tests, and retests in comparable interims ($p>0.05$), aside from test 5 performed with the left hand, in which a mean culmination time was longer in the retest than that in the post-test.

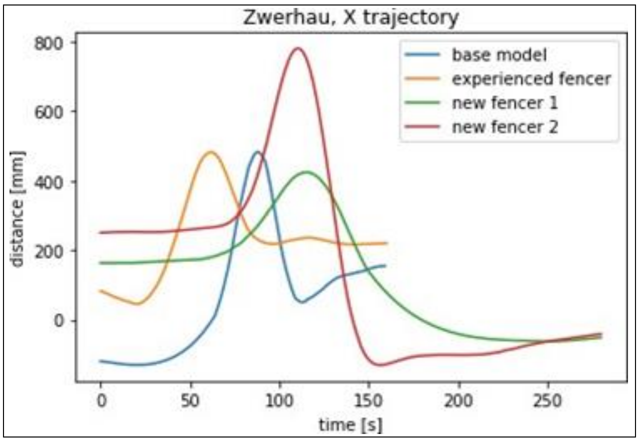

Fig 3: X Trajectories of sword tip marker, Zwerhau move

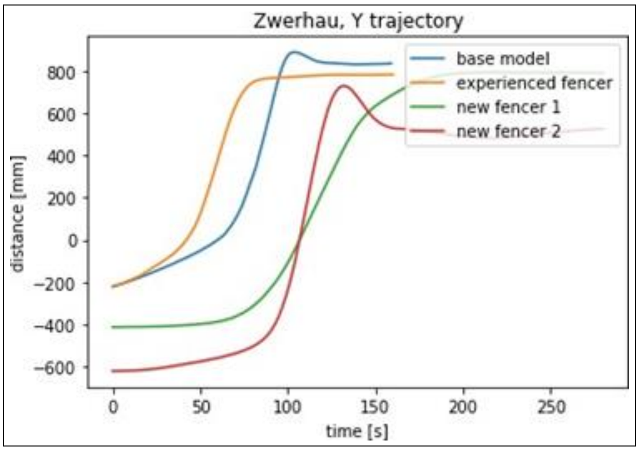

Fig 4: Y Trajectories of sword tip marker, Zwerhau move

4. Discussion

Despite clear evidence that bilateral transfer is effective in sports training, transfer training is rare among fencers. It can be useful not only in daily training, but also in training injured fencers. For example, a fencer with an injury of the dominant arm can train with the non-dominant one, thereby helping to maintain his or her special fitness. Moreover, when implemented in the early stages of training, transfer training can help increase fencers' versatility.

The results of hit accuracy testing performed with right (dominant) hands suggest a positive effect of the transfer training program used in the experiment. However, a month later the effect was undetectable, indicating the effect's short-term duration.

To explain this, we may use a cross-education phenomenon. Lee and Carroll [5] found that unilateral resistance training gives the contralateral effects, which can be due to two possible reasons: the neural adaptation and long-lasting modification of motor pathways that project to the opposite untrained limb, and induced adaptations in motor areas that are primarily involved in the control of movements of the trained limb. The opposite (untrained) limb may access these modified neural circuits during maximal voluntary contractions in ways that are analogous to motor learning. Maybe this was missing in the experimental program, which focused on coordination skills.

The processes of teaching and generalizing motor skills in fencing are undoubtedly conditioned by other factors, such as age, training experience, and level of motor skills like coordination or special orientation [6]. Fencing's unilateral nature also matters. The results of the present experiment suggested, however, that bilateral transfer-often marginalized and undervalued in asymmetric sports—can be an efficient tool in fencing training and that the speed and smoothness of motion can be efficiently transferred, corroborating Pan and van Gemmert's [47] results of a visual and motor study describing the "dynamic dominance model". Exercising the non-dominant limb can help shape the special abilities of athletes, likely enriching training and improving their performance.

Training the non-dominant hand in a continuous and systematic way can support the overall training of fencers in different age categories. The present research was planned based on the results of an earlier experiment in which transfer training had positive effects on fencers aged under 14 [12]. Starosta [11] claims that including symmetrical training supports improving asymmetric movements, thereby helping achieve better results in one-side dominant sports. Such an approach helps align both sides of the body; the greater the asymmetry of movements a discipline requires, the more intense this process should be. This idea was reflected in the experiment described here. We realized that symmetrization begins after mastering the activities with both hands, which is impossible in professional sports and does not guarantee effectiveness; therefore, we emphasized the importance of asymmetry in sport.

As follows from the above-mentioned literature and the results of the experiment on young fencers by Witkowski *et al.* [13], transfer between the dominant and non-dominant limbs can be aided by sensory feedback. An example is training by passive observation-one that is based on the idea of observational learning; during such passive observation, visual data are not controlled by the subject [8].

Other authors also confirm that symmetrical exercises positively affect the speed of learning in most-if not all-asymmetric sports and that this effect is accompanied by the feeling of relief and the decreasing of nervous tension. Wolf-Cvitak and Starosta [49] believe that thanks to bilateral transfer, symmetrical exercises help relax and develop motor coordination by forcing the second hemisphere to become more active. Their research shows that bilateral transfer from the left to the right hand has a greater effect on a learned motor function than from the right to the left hand.

In this study, the positive effects of the transfer training were short-term: Four weeks after the experimental training, they were detected for neither hand. This implies that transfer training needs to be systematic and its ad hoc use does not provide satisfactory long-term effects. Therefore, the systematic symmetrization of training will likely produce stable effects on the precision of the sensory-motor habits being learned. It should be emphasized that transfer training is especially efficient in asymmetric sports. The retention tests in this study were not performed until four weeks after completing the experimental training. Thus the benefits may have decayed sooner than four weeks and at individually different rates. The accuracy of straight thrust was used to represent fencing performance and it was acknowledged that this may not represent a competitive fencing function.

In order to provide a more in-depth picture of the use of transfer training in foil fencing training, future research should deal with various aspects of the phenomenon. First, for the moment we have no knowledge of how advanced foilists would react to transfer training. Secondly, the retention tests in this study were performed four weeks after completing the experimental training, but its effects did not last so long. It does not mean, however, that they vanish right after finishing the training-their durability is worth checking in future experiments. Thirdly, other criteria than hand grip strength and the accuracy of straight thrust might be used to assess the efficiency of transfer training. Last but not least, transfer training itself can take various forms. So, designing effective transfer training programs constitutes yet another crucial topic for in-depth research.

5. Conclusions

The six-week transfer training of the non-dominant side of fencers significantly increased the accuracy of hits and the speed of movements with the dominant arm. The results, along with those reported by Witkowski *et al.* [41], demonstrated that bilateral transfer can be effective in foil fencing training. Its effects, however, are impermanent: They disappear sometime after ceasing this type of stimulation. Thus, to maintain them for a longer time, transfer training should be applied systematically. Quite likely most of the knowledge we have gained in this study can be extrapolated to other fencing disciplines and asymmetric combat sports, but this needs to be checked experimentally. Bilateral transfer is a complex phenomenon influenced by various processes, such as lateralization, Symmetrization, and motor learning. Thus, we need to learn how the human brain functions, particularly under and after stimulation by various training techniques.

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