applied sciences

MDPI

Article

Do Hand Exercises Influence Physiological Hand Tremor? An Observational Cohort Study on Healthy Young Adults

Olga Papale [1], Francesca Di Rocco [1], Emanuel Festino [1], Viviana Gammino [2], Cristina Cortis [1,*] and Andrea Fusco [1,3]

[1] Department of Human Sciences, Society and Health, University of Cassino and Lazio Meridionale, Viale dell'Università, 03043 Cassino, Italy; olga.papale@unicas.it (O.P.); francesca.dirocco1@unicas.it (F.D.R.); emanuel.festino@unicas.it (E.F.); andrea.fusco@unich.it (A.F.)

[2] Sport and Exercise Research Unit, Department of Psychology, Educational Science and Human Movement, University of Palermo, 90144 Palermo, Italy; viviana.gammino@gmail.com

[3] Department of Medicine and Aging Sciences, University "G. d'Annunzio" of Chieti-Pescara, 66100 Chieti, Italy

* Correspondence: c.cortis@unicas.it

Featured Application: This work investigates the influence of a single session of hand exercise on physiological hand tremors. The key future directions involve developing a protocol evaluating the fine motor skills starting from wobble-board hand exercises.

Abstract: Physiological hand tremors appear to be one of the most common types of tremors that occur during the lifespan. Activities most prominently affected by hand tremors are those involving the movement of small muscles, such as fine motor skills, which in turn could be influenced by several factors, including lateral dominance. The difference in skills due to lateral dominance is defined as inter-limb imbalance or inter-limb asymmetry. When this asymmetry is attributed to the tremor and the difference in tremor between the limbs, it could be defined as the inter-limb asymmetry of tremors. This study aimed to evaluate the acute effects of wobble-board hand exercise training on the inter-limb asymmetry of tremors. Thirty-two (eighteen males and fourteen females) participants (age: 25.2 ± 2.6 years, weight: 63.9 ± 10.5 kg, height: 1.66 ± 0.8 m, and BMI: 22.8 ± 2.3 kg/m^2) were involved in the study. Before (PRE) and after (POST) the wobble-board hand exercises, postural hand tremor was evaluated using a tri-axial accelerometer fixed under the palm. Recordings were taken for 15 s. One-way Analysis of Variance (ANOVA) was used to examine the effects of hand exercises on inter-limb (dominant vs. non-dominant) asymmetry of tremor in testing time (PRE vs. POST) in relation to sex (male vs. female). The statistical significance was set at $p < 0.05$. Significant differences were found in physiological hand tremors between limbs (dominant vs. non-dominant) in the PRE evaluation ($p = 0.03$) independently from sex while no differences were found in the POST evaluation. A significant difference emerged in the PRE evaluation for males ($p = 0.04$) and females ($p = 0.03$) in relation to the testing time and preferred hand. This difference was no longer present in the POST evaluation. In conclusion, wobble-board hand exercises could represent an effective strategy to reduce inter-limb asymmetry. These results emphasize the importance of task-specific training to maximize the reduction in inter-limb asymmetry of tremors following wobble-board hand exercises.

Keywords: fine motor skills; eye-hand coordination exercise; wobble board; inter-limb asymmetry

Citation: Papale, O.; Di Rocco, F.; Festino, E.; Gammino, V.; Cortis, C.; Fusco, A. Do Hand Exercises Influence Physiological Hand Tremor? An Observational Cohort Study on Healthy Young Adults. *Appl. Sci.* **2024**, *14*, 4467. https://doi.org/10.3390/app14114467

Academic Editors: Rita M. Kiss and Alon Wolf

Received: 26 March 2024
Revised: 19 May 2024
Accepted: 21 May 2024
Published: 23 May 2024

1. Introduction

Tremor, defined as the involuntary and rhythmic movement of any body part, is the most prevalent movement disorder that affects millions of people worldwide [1]. It could be classified as physiological, essential, and Parkinsonian by means of clinical criteria [2]. Both physiological and essential tremors are characterized by involuntary tremors, usually in the hands, occurring during voluntary movements. The main difference between tremors is represented by the magnitude and clinical factors of the tremor. Physiological tremor is a low-amplitude, high-frequency (ranging from 0- to 4-Hz), involuntary tremor. It is considered normal and could be influenced by external (e.g., fatigue, caffeine intake, and stress) [3] or internal (e.g., sex) factors [4,5]. Essential tremor is a movement disorder. It may be inherited and often worsens during movement. Early essential tremor is qualitatively similar to the 4- to 12-Hz component of physiologic tremor, suggesting that it is an incomplete component of the essential tremor [6]. Parkinsonian tremor is associated with Parkinson's disease and presents as a resting tremor, decreasing during voluntary movements and increasing when the affected body part is at rest [7].

Physiological hand tremor is the most common during the lifespan and can be classified into two main forms:

- Resting hand tremor, characterized by involuntary oscillations of the hands occurring when they are at rest, without any voluntary movements [8].
- Postural hand tremors, manifested when maintaining a static position, such as holding the arms outstretched [2].

Evidence [9–11] has shown that both resting and postural hand tremor affects activities of daily living and may have a psychological impact, particularly when symptoms occur in public. Activities most prominently affected by hand tremors are fine motor skills, such as handwriting, eating, dressing, and self-care, encompassing precise and coordinated movements of the small muscles. Fine motor skills also refer to the coordination and control of small muscles, usually involving the hands and fingers, to perform precise and intricate movements. These skills are essential for tasks that require precision, dexterity, and coordination [12].

Eye–hand coordination is a perceptual–motor skill involving the integration and processing in the central nervous system of visual and tactile input so that a purposeful motor movement can be made. Eye–hand coordination is divided into probation (closed motor skill) when it refers to action initiated or controlled by the participant and reaction (open motor skill) when it refers to movement that occurs in response to another action. It is the ability of the vision system to coordinate the information received through the eyes to control, guide, and direct the hands in the accomplishment of a given task. For the improvement of eye-hand coordination tasks, different exercises and activities could be performed. Among these, the activities that make use of an unstable platform, such as a wobble board, and the manipulation of small objects, such as gaming, are considered useful strategies to increase fine motor skills and eye–hand coordination [13]. Eye–hand coordination uses the eyes to direct attention and the hands to execute and accomplish a task [14], of which a fundamental component is manual dexterity.

Manual dexterity is defined as the ability to skillfully use hands and fingers to perform intricate tasks that demand precision and coordination, involving the precise manipulation of objects and the fine coordination of manual movements [15]. It is characterized as precise, diverse, and flexible behavior that requires the coordination of many segments and can be expanded through learning. Influenced by hand dominance, it plays a crucial role in everyday life [16]. In fact, the preferred hand is usually defined as the hand that is most efficient to perform specific manual dexterity tasks (e.g., writing, manipulating objects or tools, etc.). The difference in skills due to lateral dominance is defined as inter-limb imbalance or inter-limb asymmetry [17]. When this asymmetry is attributed to the tremor and the difference in tremor between the limbs, it could be defined as the inter-limb asymmetry of tremors [17].

Several studies suggest that regular physical exercise may improve a variety of physiological and psychological factors in hand tremors [18,19]. In fact, more researchers [10,20–22] have focused their work on the effect of training interventions on the hand tremor. Studies on healthy individuals have reported an improvement in steadiness (a general term used to indicate a reduction in physiological tremor or increased precision in executing tasks requiring a high degree of motor control) as a result of structured interventions involving a physical task, such as yoga, functional and manual tasks, and light-load training. Exercise in general is defined as a protective factor of neurological capacity and cognitive impairment. Studies have shown that an increased amount of exercise in the general population leads to improved cognition, highlighting the neuroprotective benefits of physical activity [23,24]. One of the most utilized types of exercise in programs for the management of hand tremors is resistance training [25], which may provide considerable benefit to participants with a hand tremor, especially those who experience greater tremor intensity in one limb compared to the other. A previous study highlighted how a 6-week high-load resistance training program that separately exercised muscles of each forearm and upper arm, with the goal of increasing overall upper-limb strength, had a notable effect on hand tremors [22].

Although the role of exercise and physical activity is traditionally focused on strength and resistance training to improve motor control and reduce tremors in individuals with a physiological hand tremor [21,22,26], there is less evidence of the role of eye–hand coordination exercise with an unstable platform to address the inter-limb asymmetry of tremors. Inter-limb asymmetry is an important aspect to consider in physical health and exercise programs. It could have a negative impact on sporting performance and be associated with a high incidence of injuries and difficulty in carrying out daily activities [27,28]. The strongest limb may sustain excessive stress compared to the other one, resulting in unequal force absorption or a loss of frontal plane stability. Since eye–hand coordination has a significant impact on sporting performance and daily activities [28], it would be interesting to investigate the impact on hand tremors and inter-limb asymmetry. We hypothesized that participants could show a decrease in hand tremor magnitude after eye–hand coordination exercises in their non-dominant limb, reflecting the acute impact of hand exercises on inter-limb asymmetry. Furthermore, it was assumed that the effects of eye–hand coordination exercises may vary between male and female participants, particularly concerning the immediate response of hand exercises in reducing the inter-limb asymmetry of tremors. Females typically exhibit better performance in fine motor skills compared to males, potentially resulting in a reduced amplitude of hand tremor following eye–hand coordination exercises. Therefore, the main aim of the study was to evaluate the effect of eye–hand coordination exercises on the asymmetry of physiological hand tremor in apparently healthy young participants, in relation to sex.

2. Materials and Methods

2.1. Study Design

In accordance with the Declaration of Helsinki, the research protocol, designed as a cross-sectional study, was approved on 9 June 2021 by the Institutional Review Board of the Department of Human Sciences, Society, and Health of the University of Cassino and Lazio Meridionale (approval number 11748) to examine the effects of wobble-board hand exercises on the inter-limb asymmetry of tremor. This observational cohort study was conducted in the Sport and Exercise Physiology Laboratory of the University of Cassino and Lazio Meridionale. All participants gave their written consent to participate after receiving both written and oral information regarding the procedures. Participants were informed that they could withdraw from the study at any time without incurring any adverse consequences. Consent for the publication of figures was also obtained for the participant's photographs.

The inter-limb asymmetry of tremors is an important parameter often evaluated in clinical populations, such as those affected by essential tremors or Parkinson's disease. The assessment of the reduction in the inter-limb asymmetry of tremor is commonly carried out after 6-week generalized strength, resistance, and yoga interventions [22,25]. However, to the best of our knowledge, no studies have investigated the acute effect of a single session specifically focused on hand exercises. To address this gap and provide scientific evidence regarding the influence of hand exercise on the asymmetry of tremors, our study took a new methodological approach introducing wobble-board hand exercise as an effective methodology involving movement in all the anatomical body planes and axes, usually involved in all daily tasks and not considered in generalized training programs. The new methodology was ideated using dynamic tasks with real-time performance displayed to simulate the innovative hand training method, such as gaming and e-sports, which could attract several populations from athletes to sedentary participants and from children to older adults [29,30]. Considering that wobble-board hand exercise training includes hand movement in different motion patterns to promote the contraction of all the small muscles of the hand and fingers, it could provide more information on fine motor skills, in comparison with generalized strength and resistance training. Thus, to establish whether the inter-limb asymmetry of tremor could be acutely modified by hand exercise training, the assessment of hand tremor was performed before (PRE) and after (POST) hand exercises on a wobble board.

2.2. Participants

A total of 38 apparently healthy young participants voluntarily participated in this study. The study size was determined based on the sample size found in the available literature [17,31] on studies focusing on apparently healthy individuals similar in nature. Participants were recruited by means of flyers, posters, brochures, advertisements on social networks, and word-of-mouth among the student population of the University of Cassino and Lazio Meridionale.

The criteria for inclusion and exclusion were determined based on the existing literature. Since studies [5,32] have reported the influence of the aging process on physiological hand tremor, to avoid the influence of age in our evaluation, only participants aged between 20 and 29 years old were selected. Participants were also excluded if they reported pre-existing diagnosed conditions such as neurological conditions, cardiovascular, respiratory, and/or metabolic diseases, hypertension, osteoporosis, musculoskeletal injury of the back or lower extremities that had occurred during the past year, visual and vestibular disorders, or any drugs use that could influence tremor characteristics.

Considering that physical activity positively influences (i.e., reduces) physiological hand tremor [33], to avoid the influence of physical inactivity level on our sample, participants were included only if they reported being minimally active according to the International Physical Activity Questionnaire (IPAQ) [34] and be in possession of medical clearance to exercise, approved by their medical practitioner to define their healthy status [35]. Since previous research [33] reported a correlation between physical activity level and Body Mass Index (BMI), muscle mass, and body fat %, in accordance with ACSM guidelines for the clinical classification of participants [36], only participants with BMI ≤ 29.9 kg/m^2 were involved in the study. Psychological factors, such as mental fatigue, have been reported to influence hand tremor evaluation in clinical populations, such as those affected by essential tremors and Parkinson's disease [37,38], while non-clinical populations show no influence on the psychological factors of physiological hand tremors [31]. Therefore, psychological factors were not assessed in the present study as it included a non-clinical sample.

From a total of thirty-eight participants, two were excluded because they were not available to perform the POST evaluation for personal reasons and four were excluded because the accelerometers reported missing data. Therefore, a total of thirty-two participants were included in the final data analysis.

2.3. Procedures

Data collection took place at the Sport and Exercise Physiology Laboratory of the University of Cassino and Lazio Meridionale. Since the literature reported a diurnal variation in physiological tremor [39], all experimental sessions were carried out in the morning. The entire testing was conducted in a single session. Prior to the baseline evaluations, participants were familiarized with the experimental protocols. Moreover, since temperature appears to be a major determinant of tremor in humans, room temperature for data collection was kept controlled between 20 and 23 °C by an air-conditioning system through-out the experiment [40]. Irrelevant personnel were removed from the room, and the door was closed to ensure the stability of the experiment environment. Psychological stressors were minimized during the experiment by conducting the sessions in a quiet, controlled environment and by familiarizing participants with the procedure beforehand to reduce anxiety. To avoid the influence of individual habits on hand tremors, participants were required to refrain from moderate-to-vigorous physical activity and to abstain from alcohol consumption and caffeine intake for at least 24 h before the experimental sessions [21].

On average, the completion time for the data collection was approximately 1 h per participant. The timeline of the experimental procedures is shown in Figure 1.

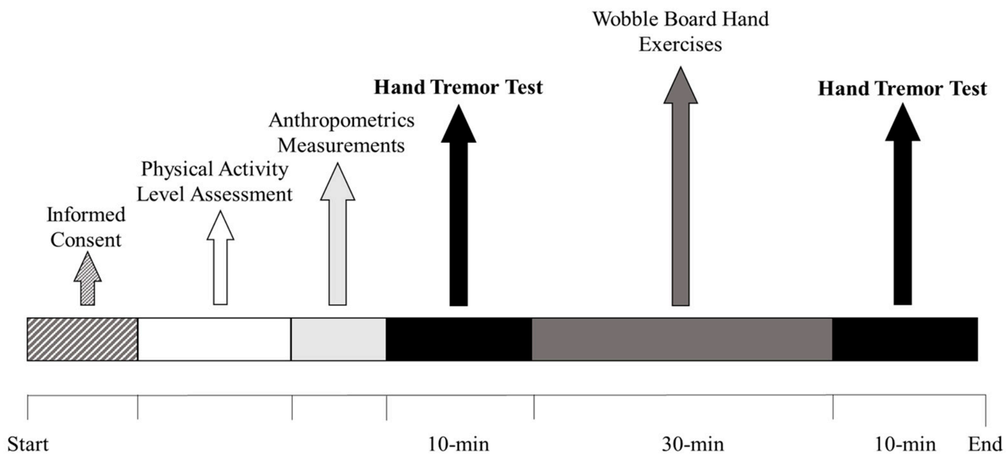

Figure 1. Timeline of the experimental procedures.

2.3.1. Anthropometric Measurements

Body weight and height were collected before starting the testing sessions using a precision instrument that combines a scale and stadiometer accurate to 0.1 kg and 0.1 cm (Seca, model 709, Vogel & Halke, Hamburg, Germany). Additionally, the body mass index (BMI) was calculated for each participant as weight (kg) divided by height squared (m^2). Participants' dominant hand was determined by asking "which hand do you write with?" [41]. The anthropometric characteristics of the participants are presented in Table 1.

Table 1. Means and standard deviations of anthropometric characteristics of participants.

	Male	Female	Total
N	18	14	32
Age (years)	24.2 ± 1.07	26.5 ± 3.5	25.2 ± 2.6
Height (m)	1.71 ± 0.6	1.60 ± 0.5	1.66 ± 0.8
Weight (kg)	69.9 ± 7.7	56.2 ± 8.3	63.9 ± 10.5
BMI (kg/m^2) *	23.7 ± 1.8	21.7 ± 2.4	22.8 ± 2.3

* BMI: Body Mass Index.

2.3.2. Hand Tremor Measurement

A tri-axial accelerometer (TalentPlayers TPDev, firmware version 1.3) was used to evaluate the postural hand tremor. TalentPlayers consists of a small wearable device integrating a 6-degree-of-freedom microelectromechanical system (MEMS) inertial sensor, able to provide acceleration and rotational data along 3 orthogonal axes. It records real-time acceleration and rotational data at a frequency of 100 Hz [42]. The device was fixed under the palm at the middle-finger level while resting the contralateral limb on the armrest and attached to the hand using a common elastic belt (Figure 2a). Recordings were taken for 15 s. Time was recorded by a stopwatch (Garmin International, Kansas City, MO, USA). The hand tremor recording started with participants' hands hanging from the edge of the armrest (Figure 2b). After 5 s, the participants were asked to extend their arms. When the participants had their arms outstretched and kept both upper limbs fully extended in front of them, with their palms facing the ground, their test was recorded for 10 s (Figure 2c). Hand tremor was recorded for dominant and non-dominant limbs before (PRE) and after (POST) wobble-board hand exercises.

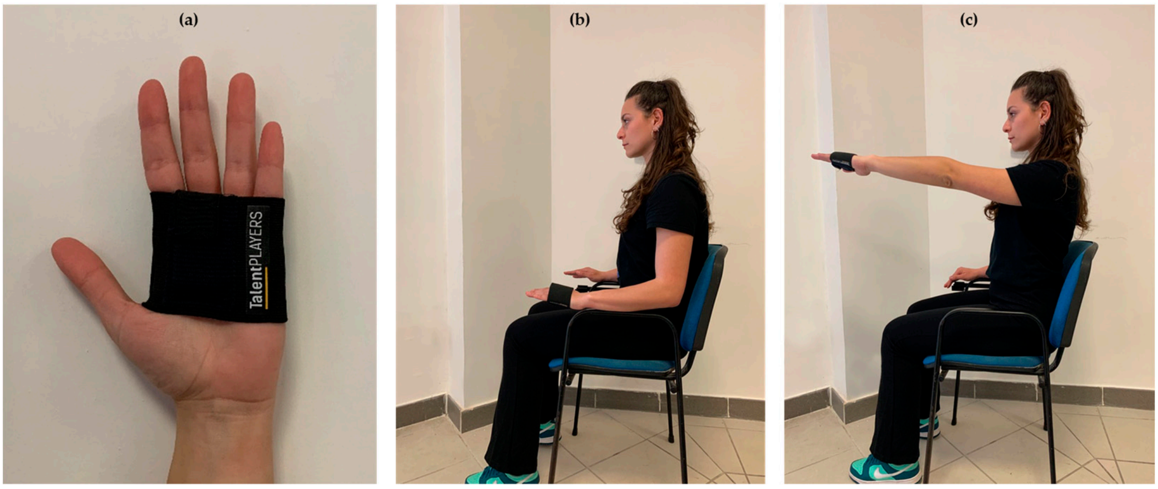

Figure 2. Tri-axial accelerometer attached to the hand using the customized elastic belt (**a**). Starting (**b**) and recording (**c**) positions of the hand during physiological hand tremor measurement.

2.3.3. Wobble-Board Hand Exercises

A computerized wobble board (Balance Board WSP, GSJ Service, Rome, Italy; 40 cm diameter with a half plastic sphere 6 cm in height and 20 cm in width; maximal tilt angle = 20°) containing a tri-axial accelerometer (Phidget Spatial 0/0/3 Basic 1041, Phidgets Inc. 2016, Calgary, AB, Canada) internally calibrated and able to measure ±8 g (±78 $m \cdot s^{-2}$) per axis and both dynamic acceleration (change in velocity) and static acceleration (gravity vector) was used to perform the hand exercises. Tilt angle data were transferred to a computer via a USB cable at 200 Hz via proprietary software (Software WSP version 1.0.0.1, GSJ Service, Rome, Italy) and displayed on the monitor (1920 × 1080 resolution screen). Participants were asked to focus on the motion marker (diameter = 6 mm) and to keep it inside the target zone (diameter = 6.5 cm) for as long as possible. The target zone stopped in the middle of the screen represents the stability area at a 0° tilt angle measured by the tri-axial accelerometer. The size of the motion marker and target zone were standard for all the participants and exercises. The wobble-board software (Software WSP version 1.0.0.1, G.S.J. Service S.r.l., Rome, Italy) user interface also displayed a countdown of 5 s before starting every exercise [43,44]. For all wobble-board hand exercises, the goal was to keep the motion marker within the target zone for as long as possible during the exercise period. The performance counter becomes active when the motion marker is in the target zone for at least one second (the integer is the only number recorded, not second fractions). The target zone displayed different motion patterns to simulate everyday motion tasks, and for all patterns, the target zone moved on the laptop for 15 s, and the details are presented below.

For Clockwise and Counterclockwise, starting from the top of the screen, the target zone started to move in a clockwise/counterclockwise motion, with the full lap taking 15 s. The displacement of the motion marker was allowed from the circular movement of the hand around the longitudinal axis.

For Antero-posterior and Medial-lateral, starting from the middle of the screen (a 0° tilt angle), the target zone moved to the top (antero-posterior) or to the left (medio-lateral) in 0.008 s and then started to move in a vertical direction (antero-posterior) or a horizontal direction (medio-lateral). The displacement of the motion marker was allowed from the movement of the hand around the frontal (antero-posterior) or sagittal (medio-lateral) axis.

Participants were in a standing position, with the working limb placed at 90° on the wobble board and the contralateral one (the limb not performing the hand exercise) resting on the same side (Figure 3a). The wobble board was placed on a table and the monitor was at eye level 2 m in front of the participant (Figure 3b). The wobble-board hand exercise included 1 min of familiarization with the unstable platform for each motion pattern, with 1 min of sitting recovery in between. After familiarization, the central phase included four 15 s trials for each motion pattern (clockwise, counterclockwise, antero-posterior, and medial-lateral) and for each limb (dominant and non-dominant) in a randomized order.

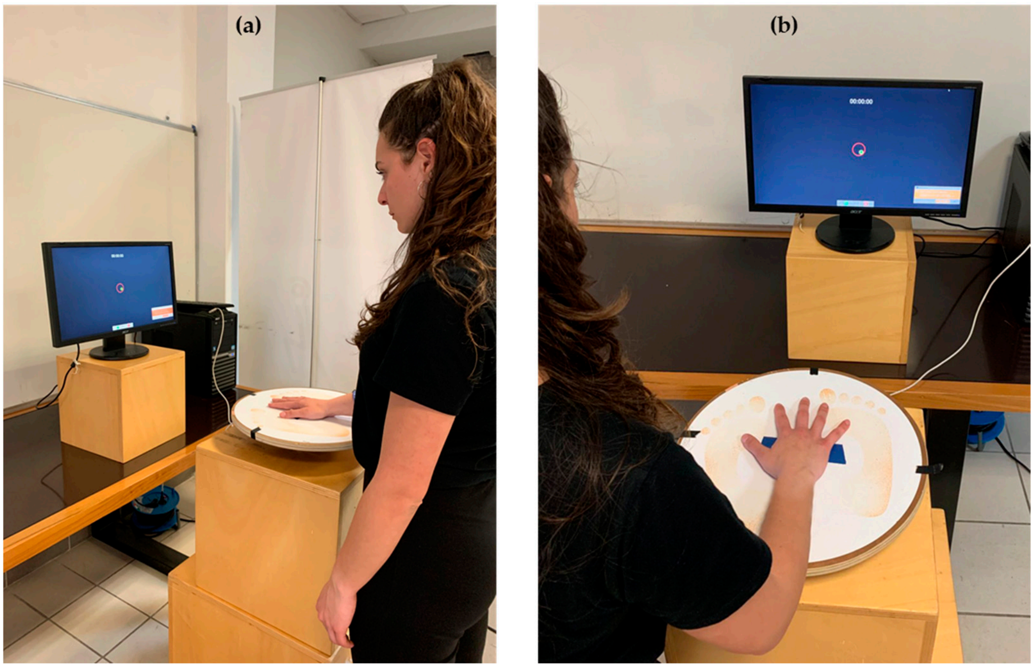

Figure 3. Standard upper-limb wobble-board hand exercise position with the working limb placed at 90° on the wobble board and the contralateral one resting on the same side (**a**) with the monitor at eye level 2 m away (**b**).

2.4. Data Extraction

In order to quantify the hand tremor, the acceleration (m/s^2) data on the x-, y-, and z-axes were recorded and then downloaded using a USB connecting cable with proprietary software (version 1.0). All data have been exported and analyzed on a Microsoft 365 Excel spreadsheet (version 2107). The means, standard deviation, total acceleration, and high-pass and low-pass Single-Pole IIR Filters for each participant, each limb (dominant vs. non-dominant), and each testing time (PRE vs. POST) were calculated.

Total Acceleration (A) [45–47] was calculated as the square root of the sum of the squares of the accelerations (SRSSa) with the following equation:

$$||a|| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Based on the previous results, the Low-Pass Single-Pole IIR Filter (LP) [45–47] was calculated as:

$$\text{LP} = 0.95 * \text{X} + 0.05 * \text{Y}$$

where X is the previous value on the LP column and Y is the previous value on the A column.

The High-Pass Single-Pole IIR Filter (HP) [45–47] was calculated as:

$$\text{HP} = ||\text{a}|| - \text{LP}$$

2.5. Data Analysis

The Shapiro–Wilk test was employed to assess the normal distribution of the data. Means, standard deviations, and 95% confidence intervals (95% CIs) were calculated for all variables. Standard deviations of the High-Pass Single-Pole IIR Filter were used for hand tremor analysis. Statistical analysis was conducted using STATA statistical software version 18 (Stata-Corp LLC, College Station, TX, USA). One-way Analysis of Variance (ANOVA) was used to examine the effects of hand exercises on inter-limb (dominant vs. non-dominant) asymmetry of tremor in testing time (PRE vs. POST) in relation to sex (male vs. female). The statistical significance was set at $p < 0.05$. In line with similar research [48], to provide meaningful analysis for significant comparisons from small groups, Cohen's effect sizes (ESs) were considered trivial for <0.20, small for an ES ranging from 0.20–0.60, moderate for an ES ranging from 0.61–1.2, large for an ES ranging from 1.21–2.0, and very large for an ES > 2.0 [49].

3. Results

Means and standard deviations of PRE and POST evaluations of physiological hand tremors are presented in Table 2.

Table 2. Means and standard deviations of the evaluation of physiological hand tremor before (PRE) and after (POST) the wobble-board hand exercise in dominant and non-dominant limbs in relation to sex.

	Male		**Female**		**Total**	
	Dominant	**Non-Dominant**	**Dominant**	**Non-Dominant**	**Dominant**	**Non-Dominant**
N	18	18	14	14	32	32
PRE (m/s^2)	0.23 ± 0.07	0.29 ± 0.09	0.20 ± 0.08	0.31 ± 0.17	0.22 ± 0.7	0.30 ± 0.12
POST (m/s^2)	0.31 ± 0.15	0.29 ± 0.17	0.18 ± 0.06	0.23 ± 0.11	0.25 ± 0.13	0.27 ± 0.15

One-way ANOVA (Figure 4) showed significant differences in inter-limb (dominant vs. non-dominant) physiological hand tremor in the PRE evaluation (df = 1; F = 9.37; p = 0.03; ES = 0.15) independently from sex. No significant differences were found in the POST evaluation (df = 1; F = 0.19; p = 0.6; ES = 0.14).

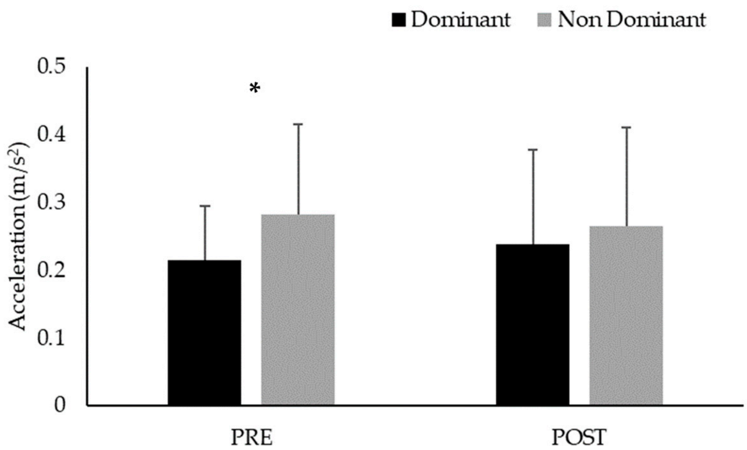

Figure 4. Means and standard deviations of the acceleration during tremor before (PRE) and after (POST) the wobble-board hand exercise for dominant and non-dominant limbs. * Significant differences between dominant and non-dominant limbs.

From one-way ANOVA analysis, sex differences were found independently of testing time and preferred limb (df = 1; F = 4.84; p = 0.02; ES = 0.39) and independently of testing time for the dominant hand (df = 1; F = 9.47; p = 0.003; ES = 0.92). No significant differences were found for the non-dominant hand (df = 1; F = 0.25; p = 0.62; ES = 0.14). Sex differences were also found in the POST evaluation (df = 1; F = 9.23; p = 0.003; ES = 0.77) while no significant differences were found for sex in the PRE evaluation (df = 1; F = 0.19; p = 0.66; ES = 0.08) as shown in Figure 5.

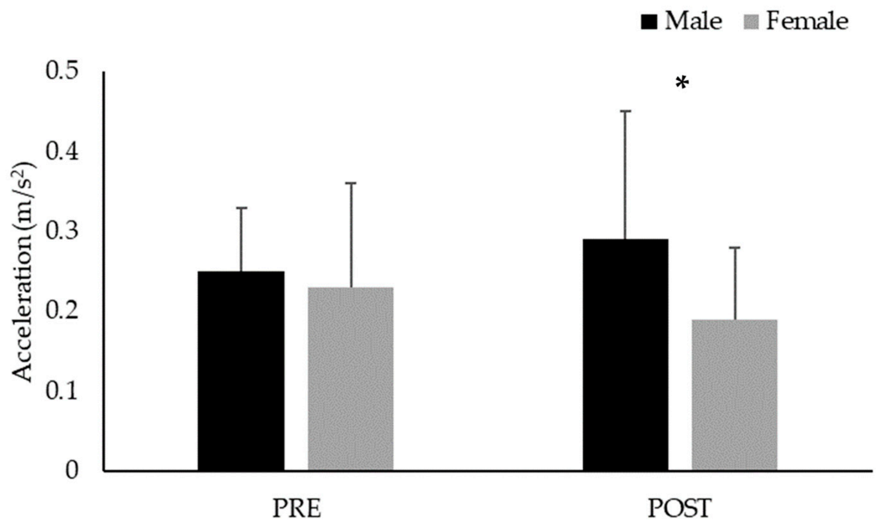

Figure 5. Means and standard deviations of the acceleration during tremor before (PRE) and after (POST) the wobble-board hand exercises in male and female participants. * Significant differences between male and female participants.

Sex differences were also found in the PRE evaluation for males (df = 1; F = 4.35; p = 0.04; ES = 0.26) and females (df = 1; F = 5.01; p = 0.03; ES = 0.89) in relation to testing time and preferred hand. No significant difference was found in the POST evaluation for males (df = 1; F = 0.09; p = 0.76; ES = 0.12) and females (df = 1; F = 2.82; p = 0.10; ES = 0.69) in relation to testing time and preferred hand (Figure 6).

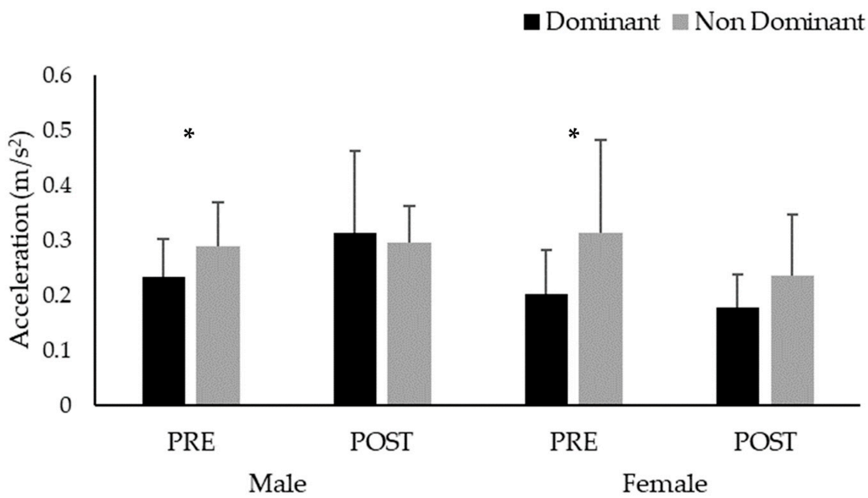

Figure 6. Means and standard deviations of the acceleration during tremor before (PRE) and after (POST) the wobble-board hand exercises in male and female participants for dominant and non-dominant limbs. * Significant differences between dominant and non-dominant limbs for males and females, respectively.

4. Discussion

The purpose of the present study was to evaluate the effect of wobble-board hand exercises on the asymmetry of physiological hand tremors in young, apparently healthy participants. The findings showed that hand exercises positively affected the hand tremor after intervention, by significantly reducing the inter-limb asymmetry of tremors for male and female participants. Moreover, the results from the present study suggested the importance of sex differences in evaluating the inter-limb asymmetry of tremors.

Physiological hand tremor is one of the most common forms of tremors worldwide. It can be influenced by several factors, among these, sex and limb dominance [5,50]. Understanding this variability is crucial when evaluating the effectiveness of therapeutic interventions, such as the utilization of an unstable platform and the manipulation of small objects.

The findings of the present study suggested that this intervention had a significant impact on inter-limb (dominant vs. non-dominant) asymmetry of tremors. Independently of sex, participants showed significant differences in terms of tremors between limbs (inter-limb asymmetry) before the intervention while this difference was no longer present after the intervention. In line with the previous results, when including sex in the analysis, significant differences were found before the intervention for males and females while no differences emerged after the intervention. The results are in line with the literature showing that activity involving the exercise of small muscles (e.g., wobble-board hand exercises and gaming) could have a positive influence on motor skills, such as eye–hand coordination, manual dexterity, and tremors, especially in terms of a reduction in inter-limb asymmetry [13].

The presence of inter-limb asymmetry of tremors was due to the higher tremor value of the non-dominant hand compared to the dominant one. The inter-limb asymmetry of tremors found before the hand exercises could be attributed to several neurophysiological and functional differences between the dominant and non-dominant limbs, such as motor control. The dominant limb is used more frequently in daily activities, such as writing, eating, and performing manual labor [51]. As a result, the muscles and central nervous system tend to have greater coordination and motor control than the non-dominant limb. Although inter-limb asymmetry occurs in a resting condition, the present study showed different behavior after eye–hand coordination exercises on a wobble board.

Another important aspect to consider is the different impact of the intervention in relation to sex. The differences between sexes observed in the POST evaluation could be explained by the different morphology of the hand. As reported in the literature, males' hands tend to be bigger than females' hands [5]. Balance exercises, such as those on a wobble board, represent a dynamic form of training that involves the displacement of the center of pressure of the hand resulting in improved physiological hand tremor control. This difference in hand size could have been responsible for producing different reactions to the same task, such as hand exercises. Focusing on these differences, the mechanisms involved in these reductions appear to differ between sexes. In male participants, the observed decrease in inter-limb asymmetry after exercise was due to an increase in tremor magnitude for the dominant hand. Conversely, in female participants, the reduction was attributed to a decrease in the tremor magnitude in the dominant hand. These findings are suggestive of sex-specific neuromuscular responses to the wobble-board hand exercise. In females, the same benefits could also be found in eye–hand coordination exercises. Wobble-board hand exercises, which involve the central nervous system, could improve proprioception and coordination between limbs, helping to stabilize tremors through better regulation of muscle tone and fine motor control. In particular, this happens in the non-dominant limb, allowing a decrease in hand tremors and a consequent reduction in inter-limb asymmetry. The reverse effect was found in males, where the increase in the magnitude of tremor in the dominant hand after exercise suggests that the wobble-board hand exercise may induce temporary neuromuscular fatigue, resulting in a decrease in motor control precision. This might be due to a greater motor unit recruitment strategy, particularly after a novel or demanding exercise [52]. Males may experience a different type of motor learning or muscular adaptation to the wobble-board hand exercise, resulting in an increase in tremor as the neuromuscular system adjusts to the eye–hand coordination performance. Conversely, for females, eye–hand coordination performance may indicate a more efficient neuromotor response to the exercise, potentially reflecting a higher propensity for fine motor control and precision tasks, which are often associated with female motor strategies. Previous studies have shown that females achieved better results in fine motor skills than males, which would explain the less difficulty during the wobble-board hand exercise and the consequent decrease in tremors in the non-dominant limb [53–55]. Considering controlled variables such as room temperature, time of data collection, age, psychological factors, drug use, and BMI, the observed differences in the impact of wobble-board hand exercises may predominantly be attributed to sex differences. While several studies have explored hand tremors in various clinical populations, there is limited research on how hand exercises affect the inter-limb asymmetry of tremors, particularly in relation to sex. The present study has identified significant effects of hand exercises on the inter-limb asymmetry of tremors in both males and females. However, the representativeness and generalizability of these findings may be limited by the specific characteristics (age and BMI class) of the participants included. Firstly, since the participants were all healthy young adults, the findings might not be applicable to other demographic groups, such as older people or those with medical conditions. While BMI is often used as an indicator of body fat, it is an indirect measure because it measures excess weight rather than excess fat or actual body fat percentage. By selecting participants with a BMI within a non-clinical weight range, we aimed to reduce variability in body fat percentages within our study sample. However, a limitation of the study is that BMI does not differentiate between fat mass and lean body mass. Additionally, the study only examined the acute (i.e., short-term) effects of a single session of wobble-board hand exercises. Therefore, future studies could investigate the chronic (i.e., long-term) effect of hand exercises on hand tremors while also considering the body fat percentage of participants.

5. Conclusions/Practical Application

Researchers and healthcare professionals continually work towards developing effective diagnostic tools and therapeutic interventions for individuals dealing with tremors. The early detection and accurate classification of tremor types are crucial for implementing appropriate management strategies. Advances in technology, including wearable devices and advanced imaging techniques, such as gaming and/or virtual reality, could contribute to better management of tremors and facilitate personalized treatment plans [56]. In conclusion, while tremors are widespread and varied, the recognition of different tremor types, especially hand tremors, underscores the need for precise diagnosis and tailored interventions to mitigate the impact of these involuntary movements on individuals' daily lives.

Thanks to the findings of the present study, health professionals could provide individualized training protocols to improve postural control and fine motor skills and perform a regular level of physical activity [57]. Moreover, these findings could be used for future comparison studies investigating a clinical population and the effects of different rehabilitative interventions, such as the practice of e-sports and gaming, aiming to improve fine motor skills performances.

Author Contributions: Conceptualization, C.C. and A.F.; data curation, C.C.; formal analysis, O.P.; funding acquisition, C.C.; investigation, O.P., F.D.R. and E.F.; methodology, O.P.; resources, C.C. and A.F.; software, O.P., F.D.R., E.F. and V.G.; supervision, C.C. and A.F.; validation, V.G.; visualization, A.F.; writing—original draft, O.P., F.D.R., E.F., C.C. and A.F.; writing—review and editing, O.P., F.D.R., E.F., V.G., C.C. and A.F. All authors have read and agreed to the published version of the manuscript.

Funding: Project ECS 0000024 "Ecosistema dell'innovazione—Rome Technopole" financed by EU in NextGenerationEU plan through MUR Decree n. 1051 23.06.2022 PNRR Missione 4 Componente 2 Investimento 1.5—CUP: H33C22000420001. O.P. and E.F.'s PhD scholarships are founded by The National reform for Recovery and Resilience (PNRR) and Pegaso University, CUP: H36E22000130001.

Institutional Review Board Statement: The study was approved on 9 June 2021 from the Institutional Review Board of the Department of Human Sciences, Society, and Health of the University of Cassino and Lazio Meridionale (approval Number 11748).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Elias, W.J.; Shah, B.B. Tremor. *JAMA* **2014**, *311*, 948. [CrossRef]
2. Deuschl, G.; Elble, R.J. The Pathophysiology of Essential Tremor. *Neurology* **2000**, *54*, S14–S20.
3. Elble, R.J. Physiologic and Essential Tremor. *Neurology* **1986**, *36*, 225. [CrossRef]
4. Shahani, B.T.; Young, R.R. Physiological and Pharmacological Aids in the Differential Diagnosis of Tremor. *J. Neurol. Neurosurg. Psychiatry* **1976**, *39*, 772–783. [CrossRef]
5. Raethjen, J.; Pawlas, F.; Lindemann, M.; Wenzelburger, R.; Deuschl, G. Determinants of Physiologic Tremor in a Large Normal Population. *Clin. Neurophysiol.* **2000**, *111*, 1825–1837. [CrossRef]
6. Louis, E.D.; Ferreira, J.J. How Common Is the Most Common Adult Movement Disorder? Update on the Worldwide Prevalence of Essential Tremor. *Mov. Disord.* **2010**, *25*, 534–541. [CrossRef]
7. Jankovic, J. Parkinson's Disease: Clinical Features and Diagnosis. *J. Neurol. Neurosurg. Psychiatry* **2008**, *79*, 368–376. [CrossRef]
8. Findley, L.J.; Gresty, M.A.; Halmagyi, G.M. Tremor, the Cogwheel Phenomenon and Clonus in Parkinson's Disease. *J. Neurol. Neurosurg. Psychiatry* **1981**, *44*, 534–546. [CrossRef]
9. Heldman, D.A.; Jankovic, J.; Vaillancourt, D.E.; Prodoehl, J.; Elble, R.J.; Giuffrida, J.P. Essential Tremor Quantification during Activities of Daily Living. *Park. Relat. Disord.* **2011**, *17*, 537–542. [CrossRef]
10. Vance, N.E.; Ulanowski, E.A.; Danzl, M.M. Yoga Led by a Physical Therapist for Individuals with Essential Tremor: An Explorative Pilot Study. *Complement. Ther. Clin. Pract.* **2019**, *34*, 17–22. [CrossRef]
11. Norman, K.E.; Héroux, M.E. Measures of Fine Motor Skills in People with Tremor Disorders: Appraisal and Interpretation. *Front. Neurol.* **2013**, *4*, 47422. [CrossRef] [PubMed]
12. Gallahue, D.L.; Ozmun, J.C.; Goodway, J. *Understanding Motor Development: Infants, Children, Adolescents, Adults*, 7th ed.; McGraw-Hill: New York, NY, USA, 2012.
13. Borecki, L.; Tolstych, K.; Pokorski, M. Computer Games and Fine Motor Skills. In *Respiratory Regulation-Clinical Advances*; Springer: Berlin/Heidelberg, Germany, 2013; pp. 343–348.
14. Nayak, A.K. Effect of Hand-Eye Coordination on Motor Coordinative Ability of Tribal Adolescents. *Int. J. Phys. Educ. Sports Health* **2015**, *2*, 328–330.
15. Jeannerod, M. The Timing of Natural Prehension Movements. *J. Mot. Behav.* **1984**, *16*, 235–254. [CrossRef] [PubMed]
16. Sobinov, A.R.; Bensmaia, S.J. The Neural Mechanisms of Manual Dexterity. *Nat. Rev. Neurosci.* **2021**, *22*, 741–757. [CrossRef] [PubMed]
17. Morrison, S.; Newell, K.M. Bilateral Organization of Physiological Tremor in the Upper Limb. *Eur. J. Appl. Physiol. Occup. Physiol.* **1999**, *80*, 564–574. [CrossRef] [PubMed]
18. Weyerer, S.; Kupfer, B. Physical Exercise and Psychological Health. *Sports Med.* **1994**, *17*, 108–116. [CrossRef] [PubMed]
19. Farashi, S.; Kiani, L.; Bashirian, S. Effect of Exercise on Parkinson's Disease Tremor: A Meta-Analysis Study. *Tremor Other Hyperkinetic Mov.* **2021**, *11*, 15. [CrossRef] [PubMed]
20. Budini, F.; Lowery, M.M.; Hutchinson, M.; Bradley, D.; Conroy, L.; De Vito, G. Dexterity Training Improves Manual Precision in Patients Affected by Essential Tremor. *Arch. Phys. Med. Rehabil.* **2014**, *95*, 705–710. [CrossRef]
21. Kavanagh, J.J.; Wedderburn-Bisshop, J.; Keogh, J.W.L. Resistance Training Reduces Force Tremor and Improves Manual Dexterity in Older Individuals with Essential Tremor. *J. Mot. Behav.* **2016**, *48*, 20–30. [CrossRef]
22. Sequeira, G.; Keogh, J.W.; Kavanagh, J.J. Resistance Training Can Improve Fine Manual Dexterity in Essential Tremor Patients: A Preliminary Study. *Arch. Phys. Med. Rehabil.* **2012**, *93*, 1466–1468. [CrossRef]
23. Öhman, H.; Savikko, N.; Strandberg, T.E.; Pitkälä, K.H. Effect of Physical Exercise on Cognitive Performance in Older Adults with Mild Cognitive Impairment or Dementia: A Systematic Review. *Dement. Geriatr. Cogn. Disord.* **2014**, *38*, 347–365. [CrossRef] [PubMed]
24. Radler, K.H.; Chapman, S.; Zdrodowska, M.A.; Dowd, H.N.; Liu, X.; Huey, E.D.; Cosentino, S.; Louis, E.D. Physical Activity as a Predictor of Cognitive Decline in an Elderly Essential Tremor Cohort: A Prospective, Longitudinal Study. *Front. Neurol.* **2021**, *12*, 658527. [CrossRef] [PubMed]
25. Kadkhodaie, M.; Sharifnezhad, A.; Ebadi, S.; Marzban, S.; Habibi, S.A.; Ghaffari, A.; Forogh, B. Effect of Eccentric-Based Rehabilitation on Hand Tremor Intensity in Parkinson Disease. *Neurol. Sci.* **2020**, *41*, 637–643. [CrossRef] [PubMed]
26. Bilodeau, M.; Keen, D.A.; Sweeney, P.J.; Shields, R.W.; Enoka, R.M. Strength Training Can Improve Steadiness in Persons with Essential Tremor. *Muscle Nerve* **2000**, *23*, 771–778. [CrossRef]

27. Guan, Y.; Bredin, S.; Taunton, J.; Jiang, Q.; Wu, N.; Warburton, D. Association between Inter-Limb Asymmetries in Lower-Limb Functional Performance and Sport Injury: A Systematic Review of Prospective Cohort Studies. *J. Clin. Med.* **2022**, *11*, 360. [CrossRef]
28. Kim, H.J.; Lee, C.H.; Kim, E.Y. Temporal Differences in Eye–Hand Coordination between Children and Adults during Manual Action on Objects. *Hong Kong J. Occup. Ther.* **2018**, *31*, 106–114. [CrossRef]
29. Pathare, S.D. A Comparative Study of Eye Hand Coordination among Games Players. *Int. J. Phys. Educ. Sports Health IJPESH* **2016**, *3*, 382–383.
30. Szturm, T.; Peters, J.F.; Otto, C.; Kapadia, N.; Desai, A. Task-Specific Rehabilitation of Finger-Hand Function Using Interactive Computer Gaming. *Arch. Phys. Med. Rehabil.* **2008**, *89*, 2213–2217. [CrossRef]
31. Budini, F.; Labanca, L.; Scholz, M.; Macaluso, A. Tremor, Finger and Hand Dexterity and Force Steadiness, Do Not Change after Mental Fatigue in Healthy Humans. *PLoS ONE* **2022**, *17*, e0272033. [CrossRef]
32. Morrison, S.; Mills, P.; Barrett, R. Differences in Multiple Segment Tremor Dynamics between Young and Elderly Persons. *J. Gerontol.-Ser. A Biol. Sci. Med. Sci.* **2006**, *61*, 982–990. [CrossRef]
33. Park, W.; Kim, B.; Lee, J.; Hong, G.; Park, J. Relationship between Physiological Tremor and Cognitive Function in Physically Active Older Women. *Phys. Act. Nutr.* **2022**, *26*, 14–19. [CrossRef] [PubMed]
34. Mannocci, A.; Di Thiene, D.; Del Cimmuto, A.; Masala, D.; Boccia, A.; De Vito, E.; La Torre, G. International Physical Activity Questionnaire: Validation and Assessment in an Italian Sample. *Ital. J. Public Health* **2010**, *7*, 369–376. [CrossRef]
35. Duncan, M.J.; Rosenkranz, R.R.; Vandelanotte, C.; Caperchione, C.M.; Rebar, A.L.; Maeder, A.J.; Tague, R.; Savage, T.N.; van Itallie, A.; Mummery, W.K.; et al. What Is the Impact of Obtaining Medical Clearance to Participate in a Randomised Controlled Trial Examining a Physical Activity Intervention on the Socio-Demographic and Risk Factor Profiles of Included Participants? *Trials* **2016**, *17*, 580. [CrossRef]
36. Thompson, P.D.; Arena, R.; Riebe, D.; Pescatello, L.S. ACSM's New Preparticipation Health Screening Recommendations from ACSM's Guidelines for Exercise Testing and Prescription, Ninth Edition. *Curr. Sports Med. Rep.* **2013**, *12*, 215–217. [CrossRef]
37. Lorenz, D.; Schwieger, D.; Moises, H.; Deuschl, G. Quality of Life and Personality in Essential Tremor Patients. *Mov. Disord.* **2006**, *21*, 1114–1118. [CrossRef] [PubMed]
38. Villarejo-galende, A.; Ferna, S. A Comparison Study of Cognitive and Neuropsychiatric Features of Essential Tremor and Parkinson' s Disease. *Tremor Other Hyperkinetic Mov.* **2011**, *6*, 431. [CrossRef]
39. Tyrer, P.; Bond, A.J. Diurnal Variation in Physiological Tremor. *Electroencephalogr. Clin. Neurophysiol.* **1974**, *37*, 35–40. [CrossRef]
40. Lakie, M.; Walsh, E.G.; Arblaster, L.A.; Villagra, F.; Roberts, R.C. Limb Temperature and Human Tremors. *J. Neurol. Neurosurg. Psychiatry* **1994**, *57*, 35–42. [CrossRef]
41. Amato, A.; Giustino, V.; Patti, A.; Proia, P.; Trivic, T.; Drid, P.; Obradovic, A.; Manojlovic, M.; Mondoni, M.; Paoli, A.; et al. Young Basketball Players Have Better Manual Dexterity Performance than Sportsmen and Non-Sportsmen of the Same Age: A Cross-Sectional Study. *Sci. Rep.* **2023**, *13*, 20953. [CrossRef]
42. Pillitteri, G.; Thomas, E.; Battaglia, G.; Navarra, G.A.; Scardina, A.; Gammino, V.; Ricchiari, D.; Bellafiore, M. Validity and Reliability of an Inertial Sensor Device for Specific Running Patterns in Soccer. *Sensors* **2021**, *21*, 7255. [CrossRef]
43. Fusco, A.; Giancotti, G.F.; Fuchs, P.X.; Wagner, H.; Varalda, C.; Capranica, L.; Cortis, C. Dynamic Balance Evaluation: Reliability and Validity of a Computerized Wobble Board. *J. Strength Cond. Res.* **2020**, *34*, 1709–1715. [CrossRef] [PubMed]
44. Fusco, A.; Giancotti, G.F.; Fuchs, P.X.; Wagner, H.; Varalda, C.; Cortis, C. Wobble Board Balance Assessment in Subjects with Chronic Ankle Instability. *Gait Posture* **2019**, *68*, 352–356. [CrossRef]
45. Sutradhar, S.R.; Sayadat, N.; Rahman, A.; Munira, S.; Haque, A.K.M.F.; Sakib, S.N. IIR Based Digital Filter Design and Performance Analysis. In Proceedings of the 2017 2nd International Conference on Telecommunication and Networks (TEL-NET), Noida, India, 10–11August 2017; pp. 1–6. [CrossRef]
46. Low-Pass Single-Pole IIR Filter. Available online: https://tomroelandts.com/articles/low-pass-single-pole-iir-filter (accessed on 26 March 2024).
47. Skogstad, S.A.; Holm, S.; Hovin, M. Designing Digital IIR Low-Pass Differentiators with Multi-Objective Optimization. In Proceedings of the 2012 IEEE 11th International Conference on Signal Processing, Beijing, China, 21–25 October 2012; pp. 10–15. [CrossRef]
48. De Maio, M.; Di Rocco, F.; Papale, O.; Festino, E.; Fusco, A.; Cortis, C. Could Mini-Trampoline Training Be Considered as a New Strategy to Reduce Asymmetries? *Appl. Sci.* **2023**, *13*, 3193. [CrossRef]
49. Hopkins, W.G.; Marshall, S.W.; Batterham, A.M.; Hanin, J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Med. Sci. Sports Exerc.* **2009**, *41*, 3–12. [CrossRef]
50. Machowska-Majchrzak, A.; Pierzchała, K.; Pietraszek, S.; Łabuz-Roszak, B. Essential Tremor–Assessment of Tremor Accelerometric Parameters' Symmetry and the Relationship between Hand Dominance and Severity of Tremor. *Neurol. Neurochir. Pol.* **2011**, *45*, 121–127. [CrossRef]
51. Incel, N.A.; Ceceli, E.; Durukan, P.B.; Rana Erdem, H.; Rezan Yorgancioglu, Z. Grip Strength: Effect of Hand Dominance. *Singap. Med. J.* **2002**, *43*, 234–237.
52. Liu, J.Z.; Brown, R.W.; Yue, G.H. A Dynamical Model of Muscle Activation, Fatigue, and Recovery. *Biophys. J.* **2002**, *82*, 2344–2359. [CrossRef] [PubMed]

53. Tiffin, J.; Asher, E.J. The Purdue Pegboard: Norms and Studies of Reliability and Validity. *J. Appl. Psychol.* **1948**, *32*, 234–247. [CrossRef] [PubMed]
54. Tiffin, J. *Purdue Pegboard Examiner's Manual*; Science Research Associates: Chicago, IL, USA, 1968.
55. Peters, M.; Servos, P.; Day, R. Marked Sex Differences on a Fine Motor Skill Task Disappear When Finger Size Is Used as Covariate. *J. Appl. Psychol.* **1990**, *75*, 87–90. [CrossRef]
56. Daneault, J.-F.; Carignan, B.; Codère, C.É.; Sadikot, A.F.; Duval, C. Using a Smart Phone as a Standalone Platform for Detection and Monitoring of Pathological Tremors. *Front. Hum. Neurosci.* **2013**, *6*, 357. [CrossRef]
57. Riebe, D.; Ehrman, J.; Liguori, G. *ACSM's Guidelines for Exercise Testing and Prescription*; Lippincott Williams & Wilkins: Philadelphia, PA, USA, 2021.