

Article

Monitoring In-Water and Dryland Interlimb Asymmetry of Young Competitive Swimmers: Insights Across a Training Macrocycle

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Abstract: This study aimed to monitor the in-water and dryland interlimb asymmetry of young competitive swimmers throughout a full training macrocycle and verify possible associations with performance. Twenty-three young competitive swimmers (12.13 ± 0.74 years) were evaluated before (M1) and after (M2) a 16-week training macrocycle. The swimmers were timed at a 25 m front crawl (T25) and then evaluated in anthropometrics, mean peak (Fpeak) in-water forces and the shoulder internal rotator's strength (IR) of dominant (D) and non-dominant (ND) limbs. The symmetry index was computed for both in-water (SyI_{water}) and dryland (SyI_{land}) environments followed by the rate of force transfer (RFT) estimation. While the swimmers have grown in height, arm span and hand surface area, accompanied by an improvement in T25, the other variables remained unchanged after the 16 weeks. A significant and moderate association was found between FpeakD ($r = -0.47$) or FpeakND ($r = -0.41$) and T25, as well as between the IRD ($r = -0.51$) or IRND ($r = -0.57$) and T25 in M1. In M2, the non-dominant side gained relevance mostly in FpeakND, showing a significant and high association with T25 ($r = -0.68$), like the FpeakD ($r = -0.69$) and IRD ($r = -0.53$). Most of the individual plots (>80%) were under 30% of SyI_{water} , with the faster swimmer values between 10 and 30%. It can be concluded that a 16-week training macrocycle is not enough to change the young swimmers' in-water and dryland symmetry, but this does not seem to affect their front crawl sprint performance.

Keywords: swimming; season; force; strength; symmetry



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1. Introduction

Symmetry plays a pivotal role in sports training, particularly in sports that require repetitive, cyclical movements such as swimming, running, and rowing [1–3]. Symmetrical athletes regularly demonstrate an exact correspondence of size, shape and actions when those are split along a given axis [4]. An athlete's ability to generate force and maintain balance between the left and right sides of the body can significantly influence their efficiency, speed and endurance [5]. Although it has been argued that sport coaches and athletes should not look for perfect symmetry [6], the early detection of exaggerated

asymmetries in cyclical sports may allow for targeted interventions, helping to improve movement quality.

Swimming is a cyclical and complex sport that requires a combination of technique, endurance and strength [7]. Symmetry in swimming refers to the balance between the left and right sides of the body during a specific movement and can be computed using swimming cycle kinematics [8], in-water forces during tethered [9] or free swimming [10] and using dryland strength ratios [11]. Asymmetries, whether in technique or muscle strength, can reduce propulsion [12], while proper bilateral coordination in force application ensures that swimmers can efficiently transfer force from their body to the water [13] and maintain velocity at desired levels [14]. Although studies reported that asymmetries rarely impact swimming performance [15], a crucial aspect of a swimmer's development is ensuring that technical skills and the physical strength of both sides of the body progress in harmony over time [16].

The performance enhancement in young swimmers involves balancing both in-water and dryland characteristics [17], which can be modulated as the competitive season occurs. Coaches often use in-water and dryland strength routines throughout a full competitive season (according to each training macrocycle) to improve the swimmer's strength capacity [18]. These kind of strategies are sequentially implemented as the training macrocycle progresses and can be rescheduled according to the swimmer's response to training. In fact, the training interventions can trigger small to moderate reductions in interlimb asymmetries from pre- to post-training programs [19]. So, the changes that may happen across a training macrocycle may highlight the physical adaptations taking place as a result of training and model the degree of symmetry in both in-water and dryland environments.

The training intervention studies focusing on symmetry in swimming are few and showed mixed findings. Unchanged symmetry values were found in adolescent swimmers after 12 weeks of training in two sequential competitive seasons [20]. On the other hand, young swimmers became more asymmetrical at the end of one competitive season without any impact on swimming performance [21]. Given this uncertainty, additional studies on symmetry in both in-water and dryland environments are needed. This is particularly important at younger ages as these are swimmers who are refining their technique while growing. So, an early detection of exaggerated imbalances can inform coaches of the necessary training adjustments in the search for the optimal dose–response relationship.

This study aimed to accomplish the following: (i) monitor the in-water and dryland interlimb asymmetry of young competitive swimmers throughout a full training macrocycle; and (ii) verify the associations between symmetry or related variables with performance and its impact at each time point of the macrocycle. It was hypothesized that (i) swimmers would remain asymmetrical in both in-water and on dryland after the training macrocycle; and (ii) there would be no associations between symmetry and performance in both time points without a negative impact on performance.

2. Materials and Methods

2.1. Participants

Twenty-three young competitive swimmers from both sexes (12 boys and 11 girls, 12.13 ± 0.74 years, 36.56 ± 3.47 s in a 50 m freestyle event) were recruited from a local swimming squad to be part of the current study. Swimmers' inclusion criteria were defined as follows: (i) be enrolled in at least four swimming training sessions per week; (ii) have more than two years of competitive experience (regional or national events); (iii) attend to all evaluation moments, and (iv) not have suffered any kind of injury in the six months prior to the intervention or between the pre and post-test measurements. None of the swimmers were excluded under the defined criteria. All the experimental procedures and risks were carefully explained to swimmers and their parents or legal guardians followed by an informed consent signature. All procedures were carried out according to the Declaration of Helsinki after the approval by the Institutional Ethics Committee.

2.2. Study Design and Training Characteristics

A longitudinal research design was selected, and swimmers were evaluated during the first training macrocycle of the season (pre and post-test measurements with 16 weeks apart). The swimmers were part of the same dynamics of training (volume and intensity), and the evaluation moments are shown in Figure 1. The in-water training volume increased from 5.4 to 18.3 km/week⁻¹, with intensity shared in the low-intensity domain (A0/A1) and velocity in the first weeks of the intervention, to be more split in low (A0/A1), moderate (A2), severe (A3) intensity domains and velocity in the final weeks of the macrocycle. Each week comprised a total of 5–6 in-water training sessions with a duration between 60 and 90 min preceded by 30 min of dryland strength work using body weight, free weights or elastic bands serving as load.

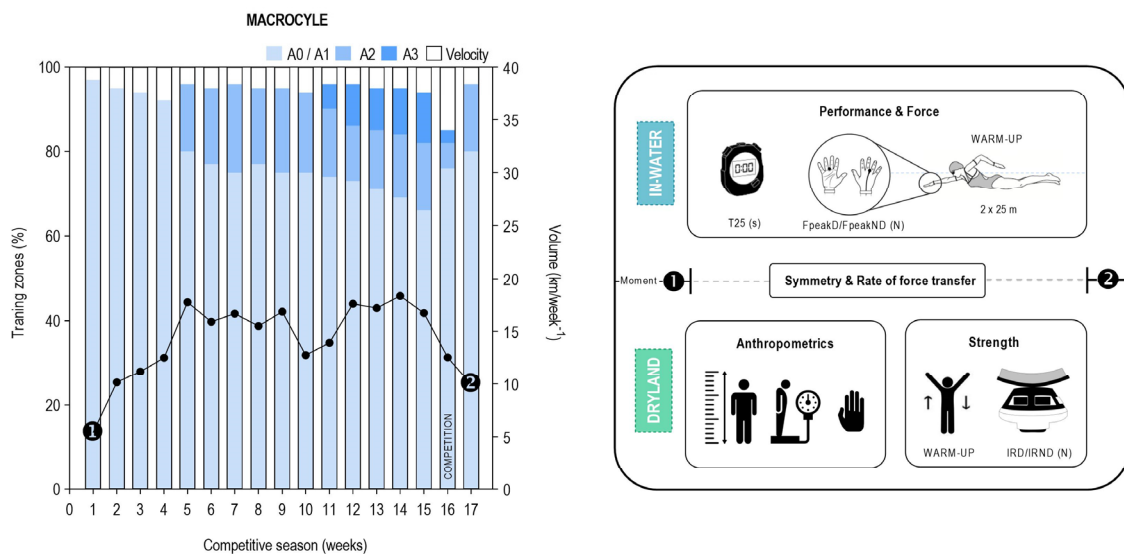


Figure 1. Training dynamics and evaluation moments during the training macrocycle: A0/A1, low intensity; A2, moderate intensity; A3, severe intensity; Fpeak, mean peak force; IR, shoulder internal rotator strength; D, dominant; ND, non-dominant; 1, evaluation moment 1; and 2, evaluation moment 2.

The evaluation moments were chosen as the beginning of the season (M1) and after the main competition of the first macrocycle (M2). Both experimental testing moments took place in the same 25 m indoor pool with 27.5 °C in water temperature and were split into two sessions (48 h apart). The first session started with the assessment of anthropometric variables followed by a standardized warm-up of a 400 m swim, 100 m pull, 100 kick, 4 × 50 m at increasing speed between each 50 m set, and 200 m recovery pace. After a passive rest of 10 min, the swimmers were randomly assigned to complete the in-water protocol. The second session comprised the application of the dryland testing protocol.

2.3. Anthropometric and Performance Measurements

All anthropometric variables were assessed by the same researcher following the recommended and standardized protocols [22]. Those were carried out with swimmers wearing normal textile swimsuits and caps. The stature (cm) and arm span (cm) were measured with a stadiometer (SECA, 242, Hamburg, Germany) and a flexible tape (Ross-Craft, Vancouver, Canada), respectively. Body mass (kg) was assessed using a digital scale (TANITA, BC-730, Amsterdam, The Netherlands), and body mass index (BMI) was estimated using the body mass and the square of height (kg/m²). The hand surface area (HSA, cm²) was measured by digital photogrammetry [23]. Swimmers placed their dominant (D) and non-dominant (ND) hands on a scanning machine, and calibration was conducted as reported elsewhere [10]. All HSA files were exported and analyzed using specific software

(Universal Desktop Ruler, v3.8, AVPSOFT, Pittsburgh, PA, USA). The hand dominance was obtained by self-report.

The swimmers made two repetitions of the 25 m front crawl at maximum intensity not gliding after an in-water push-off start and using their normal breathing pattern. The swimming performance (T25, s) was manually assessed (FINIS 3 × 100, Finis Inc., Livermore, CA, USA), and the best of both trials was considered as a performance variable to be used in further analysis.

2.4. In-Water Symmetry

The in-water symmetry was obtained from the instantaneous in-water force application during two maximum intensity repetitions at front-crawl swimming. The in-water force application was retrieved using a reliable [24] differential pressure system (Type A, $f = 100$ Hz, Swimming Technology Research, Richmond, VA, USA). The two sensors were positioned between the third and fourth metacarpals of the swimmers and attached by a cable (15 m of length) to an A/D interface connected to a laptop with the Aquanex software (v.4.1, Model DU2, Swimming Technology Research, Richmond, VA, USA). Based on the manufacturer guidelines, the calibration of the system was made before each repetition using the hydrostatic pressure values, while the swimmers kept their hands immersed (10 s) at the waistline.

The hand resultant force (N) during the maximal repetitions was derived from the product of differential pressures by the HSA individually. The force–time curves were analyzed between the 11th and 24th m section of the pool limited by two ground cones. A single camera (frequency = 50 Hz, Sony, HDR-CX 240, Tokyo, Japan) was placed in the sagittal plane, allowing image recording to avoid considering any stroke cycles made before the 11 m mark. Signal-processing software (AcqKnowledge v.3.7.3, Biopac Systems, Santa Barbara, CA, USA) was used to analyze force data, being the signal handled with a 5 Hz cut-off low-pass fourth-order Butterworth filter. The mean peak force (F_{peak} , N) of both hands was defined as the mean of the maximum peak values (i.e., peak) obtained in all subsequent underwater paths during the 13 m under analysis. Therefore, the symmetry index (SyI, in %) was estimated using the force data of both hands [25] $(F_{\text{peakD}} - F_{\text{peakND}}) / (0.5 \times (F_{\text{peakD}} + F_{\text{peakND}})) \cdot 100$, interpreted as perfect symmetry (SyI = 0%), symmetric motion ($0\% > \text{SyI} < 10\%$) or asymmetric motion ($\text{SyI} \geq 10\%$).

2.5. Dryland Symmetry

The dryland symmetry was obtained by the assessment of shoulder internal rotation strength. The isometric peak strength of internal shoulder rotation (in N) of dominant (IRD) and nondominant (IRND) limbs was measured with a reliable digital handheld dynamometer (microFET[®]2, Hoggan Scientific, Salt Lake City, LLC, USA) [26]. All swimmers underwent a 10 min dryland warm-up, including dynamic stretching routines followed by a familiarization set (one set of two submaximal and one maximal repetition by each limb) of the internal rotation. Here, the swimmers remained lying in a prone position in a stretcher with shoulder abduction and elbow flexion at 90°. The evaluator stabilized the humerus distally against the stretcher, while the handheld dynamometer was placed just proximal to the ulnar styloid process on the anterior surface of the forearm. The swimmers were instructed to slowly produce and sustain a full isometric contraction of the involved muscle group until the examiner instructed them to relax. The data were collected from two maximal repetitions of 5 s with 30 s apart. The symmetry index in dryland was computed as previously documented for in-water symmetry after the swimmers' dominance was self-reported. The rate of force transfer (RFT) was then computed for both limbs as $(F_{\text{peak}} \times 100) / \text{IR}$.

2.6. Statistical Analysis

The Shapiro–Wilk test was used to assess the data normality. The mean and one standard deviation ($M \pm 1\text{SD}$) were computed as descriptive statistics. The difference

between pre and post-tests was analyzed with a dependent sample *t*-test. Cohen *d* was selected as an effect size (*d*) and interpreted as trivial if $d < 0.2$, medium if $0.2 > d < 0.5$, and large if $d \geq 0.5$ [27]. The percentage of variation (Δ) between M1 and M2 was also calculated (e.g., $100 - [M1 \cdot 100 / M2]$). Pearson (*r*) Correlation Coefficients were computed to establish the associations between performance (T25) and symmetry; those values were interpreted as high if $r \geq 0.60$, moderate if $0.30 \geq r < 0.60$ and low if $r < 0.30$ [28]. All statistical analyses were performed using the SPSS software (v.27, IBM, SPSS Inc., Chicago, IL, USA) and GraphPad Prism (v.9, GraphPad Software, San Diego, CA, USA). The statistical significance was set at $p \leq 0.05$.

3. Results

The changes between M1 and M2 in anthropometrics, in-water force, dryland strength, performance and correspondent variables are presented in Table 1. An increase in anthropometrics, along with a T25 improvement, was seen after the 16 weeks of training. In contrast, no changes were observed in in-water force production, dryland strength, symmetry or even the rate of force transfer at the end of the macrocycle.

Table 1. Changes in anthropometrics, in-water force, dryland strength, performance and correspondent variables between M1 and M2.

Variables	M1	M2	<i>p</i>	<i>d</i>	Δ
Anthropometrics					
BM, kg	48.14 $\pm$ 8.63	48.16 $\pm$ 7.48	0.959	0.00	0.34
Height, m	156.99 $\pm$ 7.82	158.19 $\pm$ 7.82	<0.01	0.15	0.76
AS, m	157.18 $\pm$ 9.56	158.36 $\pm$ 9.81	<0.01	0.12	0.74
HSA D, cm ²	102.26 $\pm$ 11.90	106.76 $\pm$ 12.74	<0.01	0.37	4.14
In-water					
FpeakD, N	48.59 $\pm$ 11.52	49.43 $\pm$ 9.95	0.735	0.08	7.80
FpeakND, N	54.01 $\pm$ 12.79	56.88 $\pm$ 13.90	0.255	0.21	10.61
SyI _{water} , %	18.02 $\pm$ 15.21	18.11 $\pm$ 12.51	0.982	0.01	--
Dryland					
IRD, N	90.68 $\pm$ 20.03	94.82 $\pm$ 21.04	0.344	0.20	2.22
IRND, N	72.91 $\pm$ 13.70	74.49 $\pm$ 14.97	0.462	0.11	0.96
SyI _{land} , %	23.78 $\pm$ 14.34	24.97 $\pm$ 20.12	0.758	0.07	--
Performance and RFT					
T25, s	17.51 $\pm$ 1.40	16.80 $\pm$ 1.22	<0.01	0.54	−4.32
RFTD, %	55.46 $\pm$ 15.50	54.12 $\pm$ 13.79	0.698	0.09	--
RFTND, %	74.66 $\pm$ 14.13	76.38 $\pm$ 10.14	0.606	0.14	--

M1, evaluation moment 1; M2, evaluation moment 2; BM, body mass; AS, arm span; HSA, hand surface area; Fpeak, mean peak force; SyI, symmetry index; IR, shoulder internal rotation strength; T25, 25 m time; RFT, rate of force transfer; D, dominant; and ND, non-dominant.

Figure 2 presents the correlation matrix between T25 and the remaining variables in both testing moments. A moderate negative association was found between FpeakD or FpeakND and T25 in M1, while, in M2, a high negative association was observed for both variables. The IRD or IRND showed a negative and moderate association with T25 in M1, whereas, in M2, the association was just found for the IRND. The SyI in both in-water and dryland environments did not show any kind of significant association with T25 before or after the 16 weeks.

Figure 3 presents the individual dot plots of the link between T25 and in-water SyI. Although no representative trend towards an optimal SyI was shown, the faster swimmers seemed to show SyI around 10–30%. In fact, more than 80% of the dots in M1 and M2 were under the 30% SyI cut-off value.

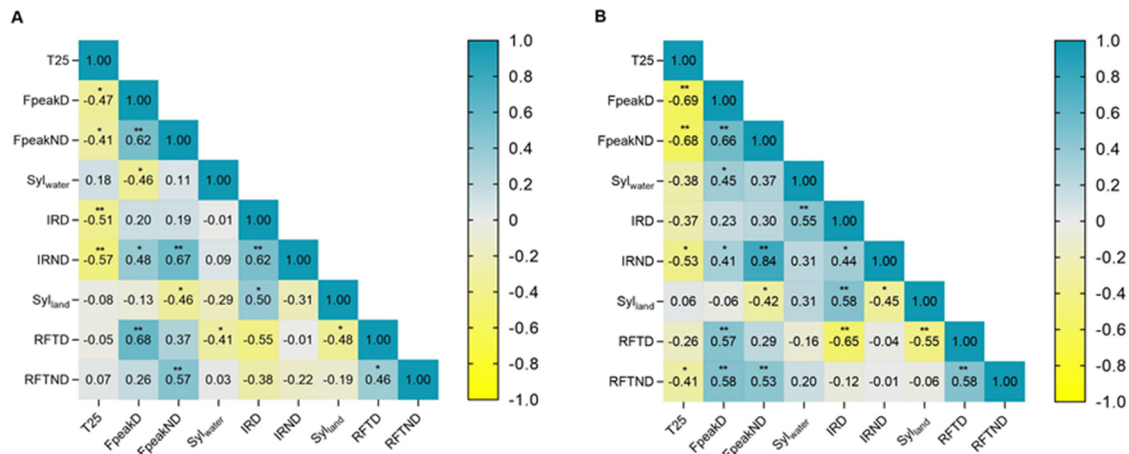


Figure 2. Correlation matrix between T25 and both in-water and dryland variables in evaluation moment 1 (A) and evaluation moment 2 (B). T25, 25 m time; Fpeak, mean peak force; SyL, symmetry index; IR, shoulder internal rotator strength; RFT, rate of force transfer; D, dominant; ND, non-dominant; * $p < 0.05$; ** $p < 0.01$.

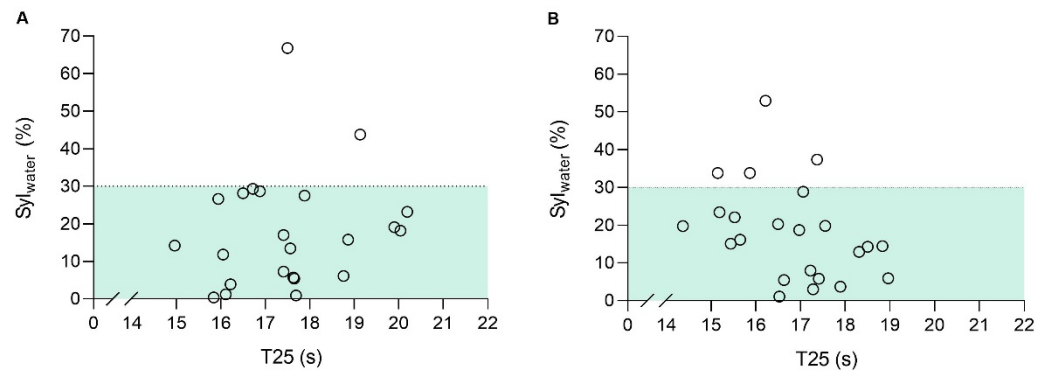


Figure 3. Individual dot plots from the link between T25 and in-water SyL in evaluation moment 1 (A) and evaluation moment 2 (B). The green area outlined by a dotted line represents the cut-off value of 30% of the in-water symmetry index. SyL, symmetry index; and T25, 25 m time.

4. Discussion

This study aimed to monitor young swimmers' in-water and dryland interlimb asymmetry throughout a full training macrocycle and to verify possible associations with performance. The results showed that young swimmers remained asymmetrical over the training macrocycle in both in-water and dryland environments without impairing performance. Although in-water and dryland symmetry were not associated with the performance, the contribution of the D and ND upper limbs gained relevance later in the macrocycle.

An increase in physical attributes along with improved performance (e.g., T25) was observed during the 16 weeks that composed the first training macrocycle of the season. Growth spurts are common in young swimmers and can naturally contribute to changes in technique and performance [21,23]. An increased AS and HSA are especially beneficial for swimmers as they can enhance stroke length [29]. Also, the increased BM, when not solely from adipose tissue, can indicate muscular development [30]. This combination of growth and targeted physical adaptations could collectively enhance overall performance, supporting the rationale that young swimmers benefit from training programs aligned with their natural growth cycles.

Interestingly, despite notable increases in anthropometric variables, no changes were observed in Fpeak, IR or even in the RFT. The unchanged Fpeak of young swimmers over prolonged periods [20] or even after a training session [31] can be found in the swimming scientific literature. As this was the first macrocycle of the season, other key aspects (e.g.,

technique refinement) may have taken the primary role in each training session, not leaving space for specific force development. The lack of change in in-water force and dryland strength indicate that young swimmers may require a longer period of training to manifest their adaptations in propulsion or need to target specific in-water and dryland strength training to obtain neuromuscular adaptations and transfer those to the water in a shorter time frame. It is unclear if the same could happen in the following macrocycles of the season or even if these results could be similar until age cohorts where swimmers are near their maximum strength development. So, those are important questions that need to be answered and can be the focus of further studies.

The SyI_{water} and SyI_{land} also remained unchanged after the 16 weeks of training, leaving swimmers to be asymmetrical while swimming front crawl ($SyI_{water} \approx 18\%$). The unchanged SyI in these swimmers suggests that anthropometric adaptations alone, such as increases in arm span and hand surface area, may not be sufficient to correct or improve bilateral force symmetry. Without targeted training, specifically aiming at addressing imbalances, young swimmers may not attenuate the existing asymmetries. In fact, work with asymmetries should be part of coaches' and athletes' daily routine as the nature of dominance persists in sports [6]. In this case, an asymmetric pattern in these swimmers was not harmful because they were still able to improve their performance from M1 to M2.

Although the 16 weeks at the beginning of the season were not enough to elicit changes, a couple of associations were found between the T25 and in-water or dryland variables. A negative association was found in M1 between F_{peakD} or F_{peakND} and T25. This means that the young swimmers who swam at a higher pace were the ones who showed a higher in-water force from the dominant and non-dominant sides of the upper limbs. In the case of the F_{peakD} , this was somehow expected as it is likely due to the initial reliance on the stronger or more coordinated side for propulsion [32]. However, the magnitude of the association increased at M2 for both sides with a more pronounced increase on the non-dominant side. As the season progresses, swimmers make technical adjustments in stroke mechanics that increase the involvement of the non-dominant side at a sprinting pace [21], especially when swimmers breathe unilaterally [33]. However, it re-mains unclear whether this trend will persist when longer distances or other breathing patterns are analyzed.

A negative association between IR and T25 was also observed in both moments. This means that a higher shoulder internal rotator's strength provides a better time at a 25 m front crawl effort, which is in line with previous studies conducted in adolescent swimmers [31]. This highlights the role of shoulder strength, particularly in the muscles responsible for the powerful inward rotation of each limb during the stroke cycle. Still, this does not mean that the superiority, in terms of force on land, can be transferred correctly to the in-water actions, as the RFT remained unchanged over the training macrocycle without associations with T25.

Despite a nuanced contribution and association between both sides of the body in distinct moments of the macrocycle, no association was found between symmetry and T25. This is in line with previous studies on the topic where asymmetries rarely impact swimming performance [14,15]. Competitive swimmers, even the younger ones, may develop techniques to compensate for minor asymmetries without negatively impacting performance. This could mean that they have adapted their body positions, breathing patterns or stroke mechanics to minimize any drag or imbalances, even with an asymmetrical force application. So, a 25 m sprint performance might rely more on the timing and coordination of rotational forces than on the equal bilateral force application. However, when longer distances come into play, as 200 or 400 m, it should be expected that some associations can be found between symmetry indexes and performance [20].

While the asymmetries are natural and part of any sport, the extent of differences in force application should be treated with caution. For instance, Bartolomeu et al. [14] concluded that the use of the 10% cut-off value to identify asymmetries seems unsuitable for adult swimmers. Through a visual inspection of Figure 3, no representative trend was found to identify an ideal SyI that allows swimmers to be faster, but those with better T25

seemed to show an SyI around 10–30%. In fact, 80% of the individual dot plots were under the 30% cut-off value, meaning that most of the swimmers belonging to the same group are asymmetrical until a certain point. This may lead us to question if a SyI higher than 30% can be detrimental for swimming technique and if this could be used as a long-term preventive measure to avoid performance decline. Although any functional asymmetry and injury risk cannot be ruled out [34], a deeper understanding about thresholds for undesired asymmetries is still needed.

When taking this into practice, the improvement of bilateral symmetry in force production may require targeted interventions, such as stroke-specific technique drills or unilateral resistance training, which could help correct any side-dominant patterns. This might also suggest that integrating asymmetry assessments over the training macrocycle could better guide the muscular training, leading to improvements in stroke efficiency and potentially reducing the risk of overuse injuries. At the end, these findings underscore the importance of monitoring symmetry in young swimmers in order to develop motor patterns and skill-specific swimming actions to guarantee that asymmetries cannot be extended to undesirable levels.

Some limitations can be assumed while conducting this study: (i) the performance measurement was restricted to a 25 m front crawl (which does not allow generalization to other swimming distances) and was manually assessed; (ii) the sample size can be low, which requires some caution extrapolating the results; and (iii) although the dryland strength was measured based on shoulder internal rotator strength, there is also shoulder adduction and extension and elbow extension during the propulsion that defines both joints' strength and potentially are responsible for the forward velocity. Future research might explore whether combining targeted dryland and in-water resistance training leads to greater improvements in force production than anthropometric gains alone and interpret how those gains may be accommodated in symmetry thresholds without impairing young swimmers' performance. Moreover, the assessment of interlimb asymmetries accompanied with the changes in the index of coordination could also be used to interpret performance adaptations.

5. Conclusions

It can be concluded that a 16-week traditional training macrocycle is not enough to change the young swimmers' asymmetric pattern confirming our first hypothesis. The in-water and dryland symmetry were not associated with the performance in both testing points, which confirms our second hypothesis. Despite that, asymmetries do not affect the sprint performance, which leaves doubt that the same may occur when longer swimming distances can be considered.

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References

1. Fohanno, V.; Nordez, A.; Smith, R.; Colloud, F. Asymmetry in Elite Rowers: Effect of Ergometer Design and Stroke Rate. *Sports Biomech.* **2015**, *14*, 310–322. [\[CrossRef\]](#) [\[PubMed\]](#)
2. Gilgen-Ammann, R.; Taube, W.; Wyss, T. Gait Asymmetry During 400- to 1000-m High-Intensity Track Running in Relation to Injury History. *Int. J. Sports Physiol. Perform.* **2017**, *12*, S2157–S2160. [\[CrossRef\]](#)
3. Knihs, D.A.; Bishop, C.; Zimmermann, H.B.; Dal Pupo, J. Between-Session Reliability of Dry-Land and In-Water Tests to Measure Inter-Limb Asymmetries in Swimmers. *J. Sports Sci.* **2024**, *42*, 737–750. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Maloney, S.J. The Relationship Between Asymmetry and Athletic Performance: A Critical Review. *J. Strength Cond. Res.* **2019**, *33*, 2579–2593. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Bishop, C.; Turner, A.; Read, P. Effects of Inter-Limb Asymmetries on Physical and Sports Performance: A Systematic Review. *J. Sports Sci.* **2018**, *36*, 1135–1144. [\[CrossRef\]](#)
6. Afonso, J.; Peña, J.; Sá, M.; Virgile, A.; García-de-Alcaraz, A.; Bishop, C. Why Sports Should Embrace Bilateral Asymmetry: A Narrative Review. *Symmetry* **2022**, *14*, 1993. [\[CrossRef\]](#)
7. Aspenes, S.T.; Karlsen, T. Exercise-Training Intervention Studies in Competitive Swimming. *Sports Med.* **2012**, *42*, 527–543. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Silva, A.; Figueiredo, P.; Soares, S.; Vilas-Boas, J.P.; Fernandes, R.J. Arm Symmetry in 11–13-Year-Old Front Crawl Swimmers. *Port. J. Sport Sci.* **2011**, *11* (Suppl. S2), 389–392.
9. dos Santos, K.; Pereira, G.; Papoti, M.; Bento, P.C.; Rodacki, A. Propulsive Force Asymmetry during Tethered-Swimming. *Int. J. Sports Med.* **2013**, *16*, 606–611. [\[CrossRef\]](#)
10. Santos, C.C.; Costa, M.J.; Marinho, D.A. The Effects of 6-Week Training Cessation on Anthropometrics, In-Water Force, Performance, and Kinematics of Young Competitive Swimmers: A Maturity Development Approach. *Int. J. Sports Physiol. Perform.* **2023**, *18*, 643–652. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Batalha, N.; Parraca, J.A.; Marinho, D.A.; Conceição, A.; Louro, H.; Silva, A.J.; Costa, M.J. The Acute Effects of a Swimming Session on the Shoulder Rotators Strength and Balance of Age Group Swimmers. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8109. [\[CrossRef\]](#)
12. Sanders, H.R.; Thow, J.; Fairweather, M.M. Asymmetries in Swimming: Where Do They Come From? *J. Swim. Res.* **2011**, *18*, 1–11.
13. Tan, J.Q.J.; Lee, M.J.C.; Boey, D.; Lum, D.; Barbosa, T.M. The Transfer of Dry-Land Strength & Power into Thrust in Competitive Swimming. *Sports Biomech.* **2024**, *23*, 443–454. [\[PubMed\]](#)
14. Bartolomeu, R.F.; Rodrigues, P.; Santos, C.C.; Costa, M.J.; Barbosa, T.M. Is There Any Effect of Symmetry on Velocity of the Four Swimming Strokes? *Symmetry* **2022**, *14*, 12. [\[CrossRef\]](#)
15. Knihs, D.A.; Bishop, C.; Zimmermann, H.B.; Dal Pupo, J. Interlimb Asymmetries in Swimming and Their Impact on Performance: Evidence from a Scoping Review. *Strength Cond. J.* **2023**, *45*, 642–662. [\[CrossRef\]](#)
16. Lätt, E.; Jürimäe, J.; Haljaste, K.; Cicchella, A.; Purge, P.; Jürimäe, T. Longitudinal Development of Physical and Performance Parameters During Biological Maturation of Young Male Swimmers. *Percept. Mot. Ski.* **2009**, *108*, 297–307. [\[CrossRef\]](#)
17. Sadowski, J.; Mastalerz, A.; Gromisz, W. Transfer of Dry-Land Resistance Training Modalities to Swimming Performance. *J. Hum. Kinet.* **2020**, *74*, 195–203. [\[CrossRef\]](#)
18. Fone, L.; van den Tillaar, R. Effect of Different Types of Strength Training on Swimming Performance in Competitive Swimmers: A Systematic Review. *Sports Med. Open* **2022**, *8*, 19. [\[CrossRef\]](#)
19. Bettariga, F.; Turner, A.; Maloney, S.; Maestroni, L.; Jarvis, P.; Bishop, C. The Effects of Training Interventions on Interlimb Asymmetries: A Systematic Review with Meta-Analysis. *Strength Cond. J.* **2022**, *44*, 69–86. [\[CrossRef\]](#)
20. Arsoniadis, G.G.; Toubekis, A.G. Effects of Successive Annual Training on Young Swimmers' Strength Asymmetries and Performance. *Appl. Sci.* **2024**, *14*, 9508. [\[CrossRef\]](#)
21. Santos, C.C.; Marinho, D.A.; Costa, M.J. Changes in Young Swimmers' In-Water Force, Performance, Kinematics, and Anthropometrics over a Full Competitive Season. *J. Hum. Kinet.* **2024**, *93*, 5–15. [\[CrossRef\]](#) [\[PubMed\]](#)
22. Lohman, T.G.; Roche, A.F.; Martorell, R. *Anthropometric Standardization Reference Manual*; Human Kinetics: Champaign, IL, USA, 1988.
23. Moreira, M.F.; Morais, J.E.; Marinho, D.A.; Silva, A.J.; Barbosa, T.M.; Costa, M.J. Growth Influences Biomechanical Profile of Talented Swimmers During the Summer Break. *Sports Biomech.* **2014**, *13*, 62–74. [\[CrossRef\]](#) [\[PubMed\]](#)
24. Santos, C.C.; Marinho, D.A.; Costa, M.J. Reliability of Using a Pressure Sensor System to Measure In-Water Force in Young Competitive Swimmers. *Front. Bioeng. Biotechnol.* **2022**, *10*, 903753. [\[CrossRef\]](#) [\[PubMed\]](#)
25. Robinson, R.O.; Herzog, W.; Nigg, B.M. Use of Force Platform Variables to Quantify the Effects of Chiropractic Manipulation on Gait Symmetry. *J. Manip. Physiol. Ther.* **1987**, *10*, 172–176.
26. Riemann, B.L.; Davies, G.J.; Ludwig, L.; Gardenhour, H. Hand-held dynamometer testing of the internal and external rotator musculature based on selected positions to establish normative data and unilateral ratios. *J. Shoulder Elbow Surg.* **2010**, *19*, 1175–1183. [\[CrossRef\]](#) [\[PubMed\]](#)
27. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Routledge Academic: New York, NY, USA, 1988.

28. Malina, R.M. Adherence to Physical Activity from Childhood to Adulthood: A Perspective from Tracking Studies. *Quest* **2001**, *53*, 346–355. [[CrossRef](#)]
29. Alves, M.; Carvalho, D.D.; Fernandes, R.J.; Vilas-Boas, J.P. How Anthropometrics of Young and Adolescent Swimmers Influence Stroking Parameters and Performance? A Systematic Review. *Int. J. Environ. Res. Public Health* **2022**, *19*, 2543. [[CrossRef](#)] [[PubMed](#)]
30. Pettersson, S.; Kalén, A.; Gustafsson, M.; Grau, S.; Caspers, A. Off- to In-Season Body Composition Adaptations in Elite Male and Female Endurance and Power Event Athletics Competitors: An Observational Study. *BMC Sports Sci. Med. Rehabil.* **2024**, *16*, 90. [[CrossRef](#)]
31. Arsoniadis, G.G.; Bottonis, P.G.; Bogdanis, G.C.; Terzis, G.; Toubekis, A.G. Acute effects of dryland muscular endurance and maximum strength training on sprint swimming performance in young swimmers. *J. Sport Sci.* **2024**, *42*, 938–946. [[CrossRef](#)] [[PubMed](#)]
32. Castañer, M.; Andueza, J.; Hilen, R.; Puigarnau, S.; Prat, Q.; Camerino, O. Profiles of Motor Laterality in Young Athletes' Performance of Complex Movements: Merging the MOTORLAT and PATHoops Tools. *Front. Psychol.* **2018**, *9*, 916. [[CrossRef](#)]
33. Tourny-Chollet, C.; Seifert, L.; Chollet, D. Effect of Force Symmetry on Coordination in Crawl. *Int. J. Sports Med.* **2009**, *30*, 182–187. [[CrossRef](#)]
34. Helme, M.; Tee, J.; Emmonds, S.; Low, C. Does Lower-Limb Asymmetry Increase Injury Risk in Sport? A Systematic Review. *Phys. Ther. Sport* **2021**, *49*, 204–213. [[CrossRef](#)] [[PubMed](#)]

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