Assessment of key factors involved in the swimming start technique: a pilot study with secondary education students

Evaluación de los factores clave que intervienen en la técnica de la salida de natación: un estudio piloto con estudiantes de educación secundaria

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Abstract. The physical education curriculum at secondary level is broad and flexible, facilitating the inclusion of sports content such as swimming, especially in schools having their own sports club. In addition to the teaching of technical elements, an evaluation may be included to provide teachers with reliable information on the achievement of objectives. The effective execution of the starting technique can be fundamental to the event performance; therefore, the aim of this study was to know and understand the influence of lower body extensor strength, ischiosural extensibility and starting angle on the swim start in young student-swimmers. Nineteen participants (15.95 ± 2.7 years) performed three starts using the Track Start technique (TS). Forward leg knee angle, lower body strength measured through various jump tests, and ischiosural extensibility using the straight leg raise test (SLR) were assessed in this study. The results showed that there was no correlation between the front leg knee angle and starting performance (T15), as well as between the swimming start variables and ischiosural extensibility. All three jumping tests showed high correlations with T15 (p = .000). The results suggest that the degree of swimmers' ischiosural extensibility is not a limiting factor in the swim start outcome. The SJ and especially the SLJ tests, due to their technical similarity, are suitable for assessing lower body extensor strength in young swimmers, as well as to predict the outcome at T15.

Keywords: physical education; swimming start; assessment; SLR test; jumping test; extensor strength.

Resumen. El currículo educativo de Educación Física en etapa secundaria es amplio y flexible, facilitando la inclusión de contenidos de deportes como la natación, especialmente en los centros con un club deportivo propio. Además de la enseñanza de elementos técnicos, se puede incluir una evaluación que permita al profesorado obtener información objetiva sobre la consecución de objetivos. La ejecución eficaz de la técnica de salida puede ser fundamental para la prueba, por ello el objetivo de este estudio fue conocer y comprender la influencia de la fuerza extensora del tren inferior, la extensibilidad isquiosural y el ángulo de salida en la salida de natación en jóvenes nadadores-estudiantes. Diecinueve participantes (15,95 ± 2,7 años) realizaron tres salidas utilizando la técnica *Track Start* (TS). En este estudio se evaluó el ángulo de rodilla de la pierna adelantada, la fuerza del tren inferior a través de diversos test de salto, y la extensibilidad isquiosural usando la prueba de elevación de la pierna recta (EPR). Los resultados exponen que no hay correlación entre el ángulo de la pierna delantera y el rendimiento en la salida (T15), así como entre las variables de salida de la natación y la extensibilidad isquiosural. Las tres pruebas de salto mostraron altas correlaciones con T15 (p = .000). Los resultados sugieren que el grado de extensibilidad isquiosural de los nadadores no es un factor limitante en el resultado de la salida. Los test SJ y especialmente el SLJ por su similitud técnica, son adecuados para valorar la fuerza extensora del tren inferior en jóvenes nadadores, así como predecir el resultado en T15.

Palabras clave: educación física; salida de natación; evaluación; test EPR; test de salto; fuerza extensora.

Introduction

Activities in the aquatic environment provide enjoyment and fun, where swimming is a versatile sport specialty, which can be focused on performance, education or recreational activities (Fernández & Baena-Extremera, 2014). It also provides a tool for coping in an environment with certain inherent risks for most children and young people. Actually, scientific literature indicates that there is a decrease in the risk of drowning when children have some aquatic skills (Mercado et al., 2016). This combined with the fact that swimming is one of the most popular recreational activities (Domínguez de la Rosa, Lezeta & Espeso, 2001; Lahart & Metsios, 2018; Sánchez-Lastra, Martínez-Lemos, Díaz, Villanueva & Ayán, 2020), and that provides to children, adolescents and the adult population with a multitude of health benefits (Lahart & Metsios, 2018), highlights the importance of incorporating swimming as a school-based content (Karantratou et al., 2020). Furthermore, these authors also consider that its promotion at school age contributes significantly to the improvement of motor skills, as a consequence of the relationship established with the comprehensive development of the student. In addition, Deluca (2013) and Fernández & Baena-

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Extremera (2014), stated that this type of practices is very attractive, fun and useful in the Physical Education (PE) lessons, since they allow the development of some basic and generic skills in the students such as jumps, turns and/or displacements. From this perspective, there are countries such as Norway, where swimming is included in the national educational curriculum, thanks to a collaboration between the Norwegian Swimming Federation and the Norwegian Department of Education. Throughout the whole educational stage, the student must acquire a series of competences and skills related to competitive swimming (Olstad, Berg & Kjendlie, 2021).

Within any sport learning process, sport technique is a fundamental part, especially in the initiation stages in order to establish the motor learning process as efficiently as possible (Chávez-Polo & Vaca-García, 2022). In this regard, concerning the technical learning process and its relationship with the swimming performance, it is well known that performance in a swimming event is understood as the result of the time spent in the start, swimming and flip turns (Taladriz, De la Fuente-Caynzos & Arellano, 2017). This includes a low reaction time, a significant applied force on the block or platform, a high take-off speed, as well as a low hydrodynamic load during water entry (Cuenca-Fernández et al., 2019). In this regard, the shorter the test distance, the more important is the performance at the start (Arellano, Moreno, Martínez & Oña, 1994; Guimarães & Hay, 1985).

Likewise, the time spent and the performance of a correct starting technique has a significant influence on the execution of the swimmer's first strokes (Vantorre, Seifet, Fernandes, Vilas-Boas & Chollet, 2010), and may be a decisive factor in the final result of the trial (Rojano & Betanzos-López, 2014). Therefore, it is essential to know the influence of the different phases of the swimming start on its immediate outcome, in order to make the necessary adjustments and to know how to focus the teaching-learning process within the sessions aimed at its improvement and efficiency (Morais, Marinho, Arellano & Barbosa, 2019; Taladriz, De la Fuente-Caynzos & Arellano, 2016).

There are several elements to consider when performing a swim start. One of them could be the extensibility of the ischiosural muscles, as this could be a limiting factor when performing a correct starting technique. Another one could be the capacity to produce force at the time of the swim start. According to López-Miñarro, Alacid, Ferragut & García (2008): "The extensibility of the ischiosural musculature is an important component of physical fitness and a key factor in the prevention of spinal pathologies and joint problems, caused by the systematic repetition of trunk flexion movements and being essential to properly perform sports and daily life activities" (p.3). A low level of extensibility restricts the range of motion limiting the execution of movements and as a consequence, impairing an adequate specific technical execution (Álvarez del Villar, 2001). Being a cyclical sport, many classical authors have considered it appropriate to develop extensibility as a tool to improve performance (Costill, Maglischo & Richardson, 2001; Navarro, Arellano, Carnero & Gosálvez, 1990). Actually, an important reason for extensibility work in swimming is injury prevention (McLeod, 2010; Sanz-Arribas, Martínez de Haro & Cid, 2016). When considering the execution of a swim start, other elements must also be taken into consideration in its execution, such as the position and angle of the front leg during the start impulse from the starting block (García-Ramos et al., 2015).

In this line, some research has measured this angle, especially when comparing different types of starts or blocks (Beretic, Durovic & Okicic, 2012; Nomura, Takeda & Takahi, 2010). The results found in both studies pointed to significant differences in the angles shaped by the front leg. These differences could be of some interest or relevance in order to check whether this angle has an influence on the start performance. This influence can be addressed when analysing the correlation between two elements: the knee angle of the front leg, and the time taken by the swimmer from the acoustic start signal until the head passes the 15-metre mark.

Regarding this starting time, the assessment of the mechanical capacity of the lower body muscles is an important element. For this purpose, vertical jump tests are frequently used due to their ability to differentiate between students with different levels of strength especially in terms of healthy physical condition values related to lower body strength (Bogataj et al., 2020; Pate, 1988). Additionally, the use of this type of test is of great relevance in swimming, since obtaining a specific mark in the jump (in height and length) seems to be closely and significantly related to the result obtained after the swim start (Petronijevic, García-Ramos, Mirkov, Jaric, Valdevit & Knezvic, 2018). Beyond the simple evaluation of technical execution in the different strokes, feedback on lower body strength levels and related factors could be obtained, detecting possible deficiencies that could explain worse times, even if the teaching-learning process of this discipline is adequate (Bogataj et al., 2020).

To date and with this type of population, especially in youth athletes with a non-high-performance approach and still of school age, no study was found analysing the relationship between ischiosural shortening and the angle of the front leg knee at the start, with the total performance of the swim start. In this regard, although there would be no apparent initial reason to believe that the shortened ischiosural extensibility would significantly influence the swim start, it would be interesting to corroborate this fact, as some students with this shortening seem not to find their ideal position and starting angle at all. It is possible that certain degree of shortening could be a limiting factor in achieving the optimum start angle with the front leg over the starting block. Perhaps, a better understanding of the relationships between the factors mentioned above in the study, together with feedback from the teacher/coach, may help them not to focus on factors that are not really relevant to the starting technique, but to pay attention to those that actually are, such as improving the explosiveness of the lower body musculature.

Moreover, conducting all these types of tests in the educational environment when swimming is included in the educational project, would allow the teacher to obtain relevant information in order to explore and improve the swimming start results and general performance in the students.

On this basis, the aim of this study was to know and understand the influence of lower body extensor strength, ischiosural extensibility and starting angle on performance during the swim start, as a possible improvement tool for the performance and technical learning process of the swim start in secondary education students. In addition, as a secondary objective, the aim was to establish the type of jumping test that correlates best with swimming start performance and would be most suitable for assessing lower body extensor strength.

Material and Methods

Participants

Nineteen swimmers, students of compulsory secondary education (ESO), participated in this study (twelve boys [63.2%] and seven girls [36.8%], aged 15.95 ± 2.7 years), belonging to a school in the province of Albacete (Spain). The sample was selected by convenience. The institute had a private swimming pool, as well as the necessary swimming equipment. All participants were members of the school's swimming team, having as preferences the swimming styles of crawl and breaststroke, and short distances (25, 50, 100 m), with a competitive regional level in most cases. This swimming programme was included in the school's educational project. The main characteristics of the sample are shown in the following Table 1.

Table 1
Characterization of the participants in the study according to GENDER

Category	Participants					
	Girls		Boys		Total	
	M	SD	M	SD	M	SD
Size (m)	1.63	0.04	1.72	0.05	1.68	0.63
Weight (kg)	53.31	5.62	61.89	5.40	58.73	6.81
BMI	19.93	1.92	21.00	2.11	20.60	2.06
Age (years)	13.86	0.69	17.17	2.72	15.95	2.71
Years of experience	6.86	3.28	8.75	3.30	8.05	3.34
Training hours (hours per week)	7.71	2.13	10.33	1.87	9.37	2.31

Experimental design and study variables

This study has a descriptive-transversal and correlational design to examine the relationship between different tests and the result in a swimming start, in order to work on different aspects for subsequent improvement.

The variables analysed in this study were the following (Table 2).

Instruments and procedures

Three types of jump tests were used to assess lower body strength, specifically related to the musculature involved and/or influencing the result of the swimming start as the phase to be evaluated (knee, ankle, hip extensor musculature): a) countermovement jump (CMJ), b) squat jump (SJ) and c) standing long jump (SLJ). Both the SJ and the CMJ are validated jump tests for the measurement of lower body strength (García-Ramos et al., 2016). A Chronojump DIN-A1 contact platform was used to perform these tests, with a Chronopic microcontroller to connect it to the computer, in addition to the Chronojump Boscosystem 1.8.1 analysis software. The SLJ is another validated jump test for measuring lower body strength (Potdevin, Alberty, Chevutschi, Pelayo & Sidney, 2011),

Table 2
Variables analysed in the study

Variable	Abbreviation	Description
Tests performed (SJ, CMJ, SLJ and SLR)		
Average power in the SJ	SJ_M_P	Average power obtained in the 3 Squat Jumps performed (N).
Average power in the CMJ	CMJ_M_P	Average power obtained in the 3 Countermovement Jumps performed (N).
Average distance in the SLJ	SLJ_M	Average distance obtained in the 3 Standing Long Jumps performed (cm).
Mean degrees of the right leg	SLR_M_R	Mean degrees obtained on the right leg after two measurements with the SLR test (º).
Mean degrees of the left leg	SLR_M_L	Mean degrees obtained on the left leg after two measurements with the SLR test (º).
Start variables		
Starting time	T15	Time taken by the swimmer from the acoustic start signal until the head passed the 15-meter line (sec) (Vantorre et al., 2010).
Starting angle	A_SAL	Angle produced on the swimmer's front leg between the hip trochanter, patella and ankle malleolus in the starting position on the block before the start (°) (Slawson et al., 2012).

N=Newtons; cm= centimetres; (º)=degrees; sec= seconds more widely used in education than the previous ones (Latorre-Román, García-Pinillos & Mora-López, 2017). To perform the SLJ, an area was marked on the ground with the jump start line and a tape measure (Lufkin W606PD) was used to take the measurement from the closest point to the start line.

For the evaluation of ischiosural extensibility, the SLR (straight leg raise) test was used being a validated test to assess the degree of ischiosural muscle extensibility (Ayala, Sainz de Baranda, Cejudo & Santonja, 2013; López-Miñarro, Vaquero-Cristóbal, Muyor, Alacid & Isorna, 2012). To perform this test, an Ultrasport™ rubber mat was used, allowing the swimmer to be placed in the supine decubitus position. In addition, a lumbar support or Lumbosant™ was used, that was placed in the lumbar region moulding itself to the lordotic curve and thus, avoiding its inversion and the tilting of the pelvis. Finally, the Acumar™ Digital Inclinometer was used to obtain the degrees of flexibility recorded in the test execution by each student. To classify the obtained values in the SLR test, the following references were used: normality (≥75°), shortness (defined as SHORT-Right) grade I (between 74° and 61°) and grade II (≤60°) (López-Miñarro et al., 2008).

To monitor the different body segments and anatomical points considered relevant during the technical execution of the start (starting angle), swimmers were fitted with yellow fluorescent polystyrene markers. These markers were placed on the ankle malleolus, the patella and the middle finger of the hands. The markers were attached to the swimmer's body using closed elastic bands fastened with Velcro. For the placement of the hip trochanter marker, swimming suits were prepared with a special surface where the exact marker position could be adjusted for each swimmer.

The block used to perform the starts was a traditional block or platform available in the school's facilities. The dimensions of the block were as follows (Figure 1):

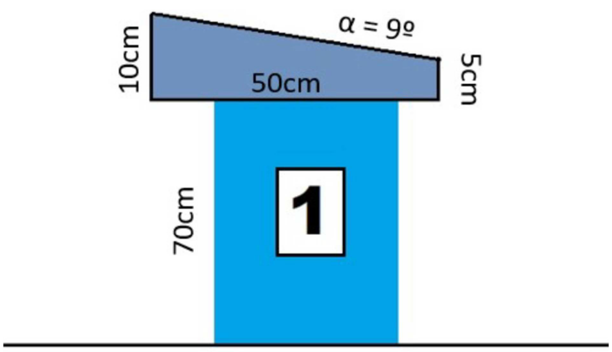

Figure 1. Starting platform or block used during the measurements

Three video cameras attached to three tripods were used for the starts recording. The video camera model was Sony HDR-PJ410B. All recordings were made with a resolution of HS-480 fps. In order to calculate T15, an electronic measuring device, synchronised with the cameras and the acoustic output signal, was used to capture the time employed by each student (Figure 2).

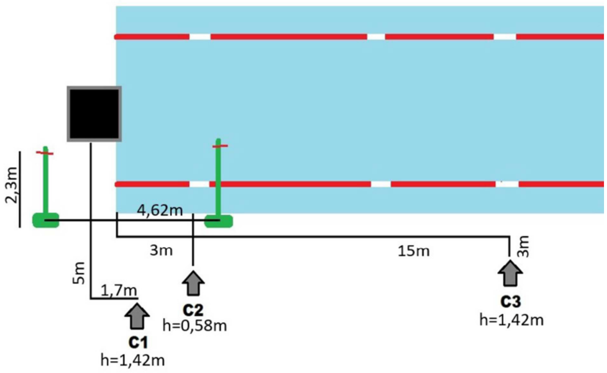

Figure 2. Location of cameras (C1, C2 and C3) and reference systems

Each participant performed three starts. The starting technique used was the Track Start (TS), due to the traditional pool without a back platform, and because this is the technique used by this students' group during the swimming lessons given at the school and the institutional swimming club. Under the indications made by the teacher/coach, each start had to be extended to 25 metres, at the maximum possible speed, and with underwater swimming that each student was normally used to doing. Participants had a 5-minute rest period between starts. The best record in T15 was used for further analysis.

Statistical analysis

All data were reported as mean (M) and standard deviation (SD). To test the homogeneous distribution of the sample, the Shapiro-Wilk test was used ($p > .05$). The correlation between the jumping tests performed, the SLR test and the start variables was studied by using Pearson's linear correlation coefficient (*r*). Its interpretation was defined under the established criteria by Hopkins (2002) (0-0.09 insignificant; 0.1-0.29 small; 0.3-0.49 moderate; 0.5-0.69 large; 0.7-0.89 very large; 0.9-0.99 almost perfect; 1 perfect). For the analysis of the "degree of shortness" of the right leg and the mean result of the SLR_right leg, a collinearity analysis was performed. For the jumping variables (CMJ_M_P, SJ_M_P and SLJ_M) a simple linear regression analysis was also performed. Finally, the effects of gender and the degree of shortness of the right leg were assessed using a 2-way analysis of variance [2(GENDER: boys and girls) x3(SHORT_R: normal, grade I and grade II)] for the dependent variable A_SAL. The Bonferroni

Post Hoc test was conducted to examine the significant differences of the interactions. A significance level of $p \leq .05$ was considered. All statistical analyses were performed using IBM SPSS Statistics 25.0 software.

Results

The main results obtained are presented below (Table 3).

This table shows the average values obtained by the participants in the jumping tests performed (SJ, CMJ and SLJ), in the SLR test and the different variables analysed in the start as well (Table 3).

Table 4
Correlation coefficients between the tests performed and the start variables

	Test									
	CMJ_M_P		SJ_M_P		SLJ_M		SLR_M_R		SLR_M_L	
Variable	r	p	r	p	r	p	r	p	r	p
T15	-.882**	.000	-.929**	.000	-.769**	.000	.565*	.012	.579**	.009
A_SAL	.198	.446	.149	.568	-.209	.421	.336	.188	.343	.177

T15: Starting time; A_SAL: Starting angle; CMJ_M_P: Average power in the Countermovement jump; SJ_M_P: Average power in the Squat jump; SLJ_M: Average distance in the Standing Long Jump; SLR_M_R: Mean degrees of the right leg; SLR_M_L: Mean degrees of the left leg

In this table 4, It is worth noting that between the CMJ_M_P (r = -.882, *p* = .000) and SLJ_M (r = -.769, *p* = .000) there was a very large inverse correlation with T15 and it was statistically very significant. Similarly, there was an almost perfect and statistically highly significant correlation between SJ_M_P (r = -.929, *p* = .000) and T15. For the ischiosural extensibility test, SLR_M_R (r = .565, *p* = .012) and SLR_M_L (r = .579, *p* = .009) had moderate and statistically significant correlation with T15 but on the contrary, none of the different tests performed had a correlation with A_SAL.

Table 5
Partial correlation coefficients between T15 and A_SAL in SHORT_R and SLR_M_R as control variables

		T15	
Control variable	Variable	r	p
SHORT_R	A_SAL	-.383	.143
SLR_M_R	A_SAL	-.436	.092

SHORT_R: Shortness_right leg; SLR_M_R: Mean degrees of the right leg; T15: Starting time; A_SAL: Starting angle

Table 5 shows the correlation between the variables A_SAL and T15 when influenced by a third control variable. For both cases, SHORT_R (r = -.383, *p* = .143) and SLR_M_R (r = -.436, *p* = .092) there was no significant correlation between the variables.

Table 6
Analysis of variance of two factors (SHORT_R and GENDER) for the dependent variable A_SAL

	gl	Root mean square	F	p	η^2
Corrected model	3	14.010	1.050	.404	.195
SHORT_R	2	20.818	1.560	.247	.046
GENDER	1	8.333	.624	.444	.194
SHORT_R*GENDER	0	-	-	-	.000

SHORT_R: Shortness_right leg; A_SAL: Starting angle

Table 6 shows that there were no significant differences in A_SAL when studying its interaction according to the GENDER of the participants ($F_1 = .624$, $p = .444$). Nor were significant differences observed in the study of their interaction related to SHORT_R ($F_2 = 1.560$, $p = .247$). It was not possible to study the interaction between A_SAL and the joint variable SHORT_R*GENDER since in girls, all of them presented a normal degree of shortness, therefore it was not possible to perform the necessary statistic.

Table 7
Mean and standard deviation of A_SAL related to SHORT_R and GENDER of the participants

		M	SD	gl	F	p
SHORT_R	Normal	144.33	3.96	1	.624	.444
	Grade I	144.50	.70	0	-	-
	Grade II	140.67	2.08	0	-	-
GENDER	Boys	143.82	3.43	2	1.560	.247
	Girls	143.50	4.41	0	-	-

SHORT_R: Shortness_right leg; A_SAL: Starting angle

Specifically, as shown in table 7, the starting angle for students with a normal shortness was 144.33° ± 3.96, while for those with shortness grade I and II, it was 144.5° ± .70 and 140.67° ± 2.08, respectively. Similarly, when comparing A_SAL according to the GENDER of the students, A_SAL was 143.50° ± 4.41 and 143.82° ± 3.43, for girls and boys, respectively. Finally, when analysing the interaction between the

Table 3
Mean and standard deviation of the results obtained by the participants in the different measurements performed according to GENDER

	GENDER					
	Boys		Girls		Total	
Variable	M	SD	M	SD	M	SD
T15	7.22	.37	8.34	.38	7.63	.66
A_SAL	143.82	3.43	143.50	4.41	143.71	3.67
CMJ_M_P	799.75	82.94	583.92	67.88	720.23	131.07
SJ_M_P	772.03	81.98	557.85	66.97	693.12	129.88
SLJ_M	215.66	17.60	171.50	19.29	199.39	28.15
SLR_M_R	73.63	15.11	91.07	5.46	80.05	14.98
SLR_M_L	76.21	14.36	92.86	6.39	82.34	14.41

T15: Starting time; A_SAL: Starting angle; CMJ_M_P: Average power in the Countermovement jump; SJ_M_P: Average power in the Squat jump; SLJ_M: Average distance in the Standing Long Jump; SLR_M_R: Mean degrees of the right leg; SLR_M_L: Mean degrees of the left leg.

inter-subject variables (SHORT_R and GENDER) for A_SAL, no significant differences were observed between groups.

Discussion

The aim of this study was to know and understand the influence of lower body extensor strength, ischiosural extensibility and starting angle on performance during the swim start, as a possible improvement tool for the performance and technical learning process of the swim start within the Physical Education/swimming lessons at school level.

The results in this study showed that the mean A_SAL reached by the students (143.71° ± 3.43) was very close to those obtained in regular swimmers by Peterson et al. (2018) (148.5° ± 11.0) and especially by Nomura, Takeda & Takahi (2010) (145.5° ± 8.0), using the same starting technique (TS) and a traditional platform or block. However, they are slightly higher than those obtained by Beretic et al. (2012) under similar conditions to our study (134.63° ± 10.58). In this study they did not calculate the time to reach 15m, but only 10m, and they did not equate the total distance to be swum to 25m as the minimum competitive test distance. In any case, it appears that the starting angle is very close to previous studies regardless of whether the sample is youth, adult, or at different competitive levels.

On the other hand, analysing the obtained correlations in our study, there is no correlation between SLR_M_R and A_SAL (r = .336, p = .188) stating that the amplitude of A_SAL in the swimmer's starting position at the outset does not have a sufficiently wide angle to be limited in its value by the degree of ischiosural extensibility held by the swimmer. Therefore, the SLR_M_R is not going to be a limiting factor in the A_SAL when the start is performed.

Concerning the correlation between A_SAL and T15, firstly, the time obtained by our swimmers in T15 was similar to other studies (Benjanuvatra, Edmunds & Blanskby, 2007; García-Ramos et al., 2015; García-Ramos et al., 2016), suggesting that we can use our data to compare with the published literature as the swimmers involved are at a similar level. Secondly, sometimes the coach might erroneously assume that the A_SAL in the swimmer's starting position at the outset could define the rest of the execution and, as a consequence, the outcome of the start (i.e., T15). However, after the analysis of the results, it is observed that the A_SAL does not have any correlation with the result in the start (T15). No significant correlation between A_SAL and T15 (r = -.153, *p* = .558) were found, being in line with the study by García-Ramos et al. (2015) establishing that there was no correlation between both aspects as well (r = .00). Taking into consideration the previous statements, we could establish that the degree of SLR_M_R of the swimmer is not going to be a determining factor in the result of the swim start. This statement can be confirmed by performing the correlation between A_SAL and T15 using the control variables SHORT_R (r = -.383, *p* = .143) and SLR_M_R (r = -.436, *p* = .092). There is no significant correlation using ischiosural extensibility as a control variable. In this case, the ischiosural extensibility values presented in the analysed athletes were not low enough to compromise the start and the T15. Therefore, no significant correlation using ischiosural extensibility as a control variable could be used by the coach in order to obtain valuable information.

On the other hand, analysing the obtained results in the different jumping tests performed, we found a large negative and statistically very significant correlation between CMJ_M_P (r = -.882, *p* = .000) and SLJ_M (r = -.769, *p* = .000) with the start performance (T15). In addition, an almost perfect and highly significant inverse correlation was found between SJ_M_P (r = -.929, *p* = .000) and start performance, understood as T15. These high values in the correlation between the lower body strength estimation through the jump test, and the result at the start, highlight the importance of the force output over short periods of time in swimmers. These results are consistent with those previously found by Carvalho et al. (2017) with a similar correlation (r = -.82, *p* = .002) between CMJ_M_P and T15. However, comparing our results with those obtained by García-Ramos et al. (2016), large differences are observed in the force output values obtained both in absolute terms (720.23 ± 131.07 *vs.* 1403.3 ± 176.4) and in relative terms (12.20 ± 1.21 *vs.* 23.72 ± 1.46) in the CMJ, as well as in the SJ in absolute (693.12 ± 129.88 *vs.* 1273.1 ± 191.5) and relative terms (11.74 ± 1.34 *vs.* 21.59 ± 2.80). These large differences in the results are possibly due to the very different sample used, since García-Ramos et al. (2016) used much more experienced swimmers and higher competitive level, which implies a very specific strength training in sessions, something that the swimmers-students in our study did not have. Furthermore, it should be noted that they found no significant differences between the CMJ_M_P (r = -.012) and the SJ_M_P (r = -.014) related to T15. This result may lead us to believe that the higher the competitive level and strength levels of the swimmers, the less important is the force exerted on the block and the take-off speed in the overall performance of the swim start. On the contrary, the study conducted by Keiner, Yaghobi, Sander, Wirth & Hartmann (2015) rejected this idea, since they established an inverse and almost perfect correlation between CMJ_M_P (r = -.92) and SJ_M_P (r = -.94) with T15 in swimmers of highly competitive level, as well as the previously mentioned study conducted by Carvalho et al. (2017), who analysed swimmers of the Portuguese Olympic team and established a very large inverse correlation between CMJ_M_P and T15.

It should be noted, that we also introduced a third jumping test, the SLJ, since we consider that its technical characteristics are more similar to the execution of the swimming start (a jump in the horizontal plane rather than in the vertical plane, as occurs in the CMJ and SJ). For this reason, we cannot compare our results with those obtained in the literature, since to the best of our knowledge, the SLJ had not yet been compared with the performance in the swimming start.

In this regard, after observing the similar correlation values between the different jumping tests (CMJ, SJ and SLJ) related to the T15, it is noteworthy that, although the SJ showed the best results in the correlation study (r = -.929, p = .000) in addition to being a simple method for the assessment of lower body explosive strength in swimmers, the countermovement jump and the vertical jump could be less appropriate for training and/or prediction of swimming start performance compared to the SLJ. The main reason may lie on the fact that the SLJ is a horizontal jump (same plane that the swimming start) and without counter movement, that is, without the intervention of the elastic force acquired in the downward movement of the body prior to the jump, so it is the one that most resembles the effective execution of a swimming start.

Conclusions

After conducting this study in non-high performance and school-aged youth student-swimmers, we can confirm that having a shortness in the ischiosural musculature (grade I or grade II) will not have an impact on the ability to reach the optimal angle of the front leg in the initial phase of the swim start. Likewise, there is no correlation between the angle of the front leg and the performance at the start (T15), so we can state that not being able to reach the amplitude of the theoretical optimum angle will not have any negative repercussions on the swim start. In view of these results, it may be concluded that ischiosural extensibility is not a limiting factor in the swimming start, so that it will not be a limiting issue for students/swimmers when conducting such practical and technical sessions in both environments, in physical education lessons as well as training sessions with the club. On the other hand, the different lower body strength estimation tests used in this study (SJ, CMJ and SLJ) have a very high correlation with the result in the swimming start (T15). In addition, even if the three different jumping test showed very good values and it would be adequate to use it for evaluative purposes, the SLJ seems to be most specific and suitable for assessing lower body extensor strength in swimmers and, a good test in order to obtain an approximated knowledge concerning the potential result in the swimming start. Therefore, it could be used as a tool for assessment and prediction of starting performance by the teacher or coach.

Moreover, it would be interesting to explore in the future into other parameters involved in the swimming start performance, especially with the distance covered in the first 15 metres, such as the swimmer's sliding, the execution or non-execution of breathing, as well as the length of the stroke. Subsequently, possible relationships and explanations related to those factors already analysed in this manuscript could be found in order to obtain a better understanding.

The possible relationship of the SLR test to different back leg angles and positions, how it might affect power output at the start, or examine possible correlations relative to specific anthropometric measurements could also be studied.

Finally, some of these factors mentioned could also be investigated in other technical elements such as the swimming turn, where in addition to specific parameters such as speed, amplitude and stroke frequency, the performance in the CMJ test could be related to the power output developed during the swimming turn technique.

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Declaration of interest statement

The authors report there are no competing interests to declare.

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