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STRENGTH AND HANDEDNESS IN ADOLESCENTS: THE IMPACT OF SPORT PRACTICE ON LATERALITY CONSOLIDATION[i]

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Abstract:
Handedness (upper limb laterality) should be a cornerstone of motor skill development and sport performance in youth. However, many environmental and social factors affect laterality consolidation (LC) during development. It was our aim to analyze the influence of out of school sport practice (OSSP) on LC. 249 adolescents from the same high school were selected for this study. Handedness was assessed by a laterality quotient (LQ) calculated from an adapted questionnaire. Handgrip isometric strength tests were carried out both left and right hand to confirm the dominance agreement with LQ. Right-handedness students showed higher right vs. left strength difference than left-handedness (2.25 and -0.91kg; P<0.05). There were a higher proportion of LC in the group of adolescents with OSSP than those without OSSP, both in left (LH) and right-handedness (RH) (OSSP: RH, 80% and LH, 77.4% vs. non-OSSP: RH, 66.7% and L,H 41.7%; P<0.05). Our main finding was that there was higher probability of LC among adolescents involved in OSSP. Also, a simple inventory and handgrip strength test may be useful tools in order to assess LC, which can help to reinforce laterality in adolescents.

[i] FUERZA Y PREFERENCIA MANUAL EN ADOLESCENTES: EL IMPACTO DE LA PRÁCTICA DEPORTIVA EN LA CONSOLIDACIÓN DE LA LATERALIDAD

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Keywords: laterality quotient, hand dominance, grip strength, high school students, sport training

Resumen:
La preferencia manual (lateralidad del miembro superior) debería ser una parte fundamental del desarrollo de la competencia motora y el rendimiento deportivo durante la juventud. Sin embargo, existen numerosos factores sociales y medioambientales que afectan a la consolidación de la lateralidad (LC) durante el desarrollo. El objetivo de este estudio fue analizar la influencia de la práctica deportiva fuera de la escuela (OSSP) en la LC. Para ello 249 adolescentes del mismo Instituto de Educación Secundaria Obligatoria fueron seleccionados. La preferencia manual fue evaluada con el coeficiente de lateralidad (LQ) calculado utilizando un cuestionario especifico adaptado. Se realizó un test de fuerza isométrica de prensión manual derecha e izquierda para confirmar la concordancia con el LQ. Los estudiantes con preferencia manual derecha mostraron una diferencia de fuerza entre la mano derecha y la izquierda mayor que los del grupo de preferencia manual izquierda (2,25 and -0,91kg; P<0,05). Hubo una mayor proporción de LC en el grupo de adolescentes con OSSP que en el grupo sin OSSP, tanto para zurdos (LF) como para diestros (RH) (OSSP: RH, 80% and LH, 77,4% vs. non-OSSP: RH, 66,7% and LH 41,7%; P<0,05). Nuestro principal hallazgo fue, por tanto, el hecho de una mayor consolidación de la lateralidad entre los adolescentes del grupo que practicaba deporte. Además, un simple cuestionario y test de fuerza de prensión manual pueden ser buenas herramientas para evaluar la LC, lo cual puede ayudar a reforzar la lateralidad en adolescentes.

Keywords: cociente de lateralidad, dominancia manual, fuerza de prensión, estudiantes de secundaria, entrenamiento deportivo

1. Introduction and Literature Review

Motor skill capacity development (MSD) are considered an important goal in physical education classes (PE) and sport training with young athletes, since they are on the base of overall motor skills learning. The acquisition of basic motor skills is a cornerstone for a children's healthy development and for the optimization of motor sport skills during adulthood[1]. As children mature the fundamental MSD learned at a younger age are applied as specialized skills in different sports, games and recreational activities. An example being the fundamental skill of striking a ball, which progresses into the use of a racquet, club or bat in recreational pursuits such as golf and baseball. With this knowledge, PE classes and sport practice should contain strategies related to teaching-learning processes, focusing on promoting an optimized development of MSDs.

The preferred bodily side to perform the common daily activities is a MSDs known as laterality, which is determined by brain dominance[2-4]. However, dominant side is not the same for lower and upper limbs, and trunk, depending on the type of task performed.

The natural preference of the dominant side is termed handedness, for the hand, footedness, for the feet, and laterality, for the whole body.

Handedness is one of the most studied components of laterality[5], which is defined as the dominant hand. Some authors have proposed different approaches, such as: a) the relative preference for one hand in the execution of various unimanual tasks[6,7]; b) the hand which presents the best skillfulness to perform daily tasks[7,8]; c) the strongest hand[9].

It is reasonable to suggest that a correct definition of handedness should be a mixture of these three, above stated, components. Oldfield proposed in 1971, with a simple questionnaire constructed to assess hand laterality[10]. All items in this questionnaire are recoded into a final score, the laterality quotient (LQ), which ranges between -1 and 1. Therefore, LQ give us a continuous variable of right or left-side dominance grade (-1 left handedness 100%, 1 right handedness 100%, 0 ambidextrous). Because the items used for LQ assessment are based on common daily tasks, one limitation of this questionnaire is that the scores may not reflect true hand dominance for specific tasks, such as those presented in different sports, thereby altering the questionnaire result. For this reason, the use of LQ as continuous variable has been suggested alternatively (see methods section).

During PE and sport practice, the use of questionnaires to assess handedness can be biased due to teaching strategies. Worldwide motor skills teachings are in a right dominant fashion, and several children and adolescents may change their laterality. Handedness must be determined by heritability[11], social and environmental conditionings as physical education learning have been suggested to change the natural tendency to handedness[12-14]. Mistaken handedness selection can originate learning difficulties[15,16]; Thus, there needs to be an established variable method to determine the grade of laterality consolidation (LC), which we have suggested as the coincidence among, skillfulness hand for daily activities (assessed by LQ), strongest hand (difference between right and left hand-grip strength) and self-reported handedness (natural preference).

The coincidence of grip strength and handedness (assessed by LQ and self-reported) may be considered a plausible method to confirm laterality, since strong and skillful upper limb use should coincide with daily activities. In the present study we utilize this understanding to explore the laterality in upper limbs. Specifically, since in the common life, where many environmental aspects could have modified the natural handedness; in instance, knobs position, car gears or notebooks have been classically designed for right-handedness users, so many children could have changed their natural dominance as adapting to environment. We speculate that due to the fact sport practice do not promote hand and predetermined field-side use (playground are symmetric and young athletes can obtain improved performances in any area), adolescents involved in out-of-school sport practice (OSSP) will be most provable to have better LC.

The aims of this study were: first, to observe the relationships between handedness and hand-grip strength. Second, to analyze the influence of OSSP in the relationship of handedness and hand-grip strength. Our hypothesis is that handedness and strength

would be a lower percentage of disagreement between handedness and grip strength among adolescent with high incidences of OSSP.

3. Material and Methods

3.1 Experimental Approach

A study advertisement during PE classes and recess were performed to recruit the sample. Initially, one hundred and sixty-two students were enrolled in the study. After analysis of the self-assessed handedness questionnaire, twenty additional left-handed participants from a sample of eighty-seven were enrolled; to meet minimal criteria for statistical analysis, specifically cells ratio and power. Assessments and questionnaires were performed during PE classes, on the same day.

3.2 Subjects

Two hundred and forty-nine healthy adolescents (113 girls and 136 boys) participated in the study (age, 15.4 ±1.5 years; weight, 59.5 ±14.0 kg; 21.9 ±4.3 kg/m^2). All adolescents were students in the same high school at the metropolitan area of Malaga city (Andalucia, Spain). All evaluated adolescents presented a healthy BMI range. Girls were significantly younger than boys (-0.55 years, P<0.01), and also presented less height and weight than boys, despite their BMI was not significantly different. The Institutional Review Board of the Sports Medicine School of the University of Malaga approved all procedures used in this study. Afterwards, all adolescents that accepted to participate had parents or guardians sign the written informed consent and a medical examination was performed to confirm that the students were eligible to participate. Adolescents that presented with chronic disease or acute injury to the upper extremities were excluded from the analysis.

3.3 Procedures

3.3.1 Strength Assessment

Hand-grip strength was measured on both non-dominant and dominant hands using a hand-held dynamometer with adjustable widths (Takei Hand Grip Dynamometer, Digital display). From standing position, students were instructed to squeeze the dynamometer as hard as possible for 3 seconds, without pressing the instrument against their body or bending at the elbow (the elbow position was set at 180º of extension). The free upper limb could not touch any external object or the dynamometer. Trunk bending, lower limb flexion, displacement or any other movement was permitted. Two measurements were taken in each hand. A 3 to 5-min rest interval was instructed after each hand tests (first tested hand was random).

3.3.2 Laterality

Laterality was assessed with an 11-item questionnaire, used to calculate LQ. Calculations were performed using the procedure proposed by Oldfield[10]. However, we used only

eleven items to perform the calculations (see Appendix). After participant tabulated items were put into the equation used to calculate LQ (equation 1).

$$LQ = 100 \frac{\sum_{i=1}^{11} X(i,R) - \sum_{i=1}^{11} X(i,L)}{\sum_{i=1}^{11} X(i,R) + \sum_{i=1}^{11} X(i,L)}$$

Equation 1

We use LQ to define laterality as stated due to the fact that this is a simple basic motor skill, which is conditioned by brain dominance, the true physiologic determinant of laterality. Because it is possible that the best performance of overall daily tasks would not be conducted using the same body side, we will consider laterality as a continuous variable, instead of an absolute value. Moreover, there is a linear relationship between learning disorders and laterality in children[16], so a favorable LQ should be an important tool for PE educators and health educators. The optimal grade of LQ has not yet been determined; however, the consolidation of hand skillfulness is important for children development and it has been suggested that selected physical and intellectual abilities can be affected by a weaker hand motor function[15].

3.3.2 Laterality Consolidation

Two criteria were used to estimate the laterality consolidation: first the coincidence between self-reported handedness assessment and LQ (positive value indicate right-handedness and negative left-handedness). Secondly, the coincidence of the strongest hand (handgrip strength) and LQ. When both criteria matched, we assumed students had their laterality consolidated.

3.4 Statistical Analysis

Results are presented as means and standard deviation (SD) for parametric analysis, and as percentages and frequencies for non-parametric analysis.

Strength difference between right and left hand was calculated using the best trial of two attempts. Strength differences between subjects with left and right-handedness were compared using independent sample T-test.

The sample was divided into several groups in order to create cross tabulation for chi-square analysis, namely: left and right-handedness using both self-assessment handedness and LQ; students stronger with right or left hand; students with OSSP or without OSSP (N_OSSP); also, a combination of all (table 1). A 2x2 Chi-square analyses were performed in order to calculate the probability of having significant between-group (self-assessed handedness) difference on strength with dominance hand. Agreement between handedness assessment by LQ and self-reported (self-assessed handedness) was also analyzed using chi-square.

Second, a 2x4 Chi-squared analysis was carried out to explore significant differences between-groups (stronger in left or right hand) on handedness group (left or right) also split by OSSP (practice or not practice, Table 1).

Table 1: Theoretical cross-tabulation summarizing groups for 2x4 chi-square analysis

Dominance by LQ	**Out-School Sport Practice (OSSP)**	**Students stronger with right hand (SR)**	**Students stronger with left hand (SL)**	**Totals**
Right-Handedness (RH)	OSSP	RH OSSP&SR (a)	RH OSSP&SL (b)	a+b
	N_OSSP	RH N_OSSP&SR (c)	RH N_OSSP&SL (d)	c+d
Left-Handedness (LH)	OSSP	LH OSSP&SR (e)	LH OSSP&SL (f)	e+f
	N_OSSP	LH N_OSSP&SR (g)	LH N_OSSP&SL (h)	g+h
Totals		a+c+e+g	b+d+f+h	Total

Analysis of individual cases were explored in a (spaghetti chart) bar figure, in order to observe the width of strength differences, either for left-handedness or right-handedness students, and also the percentage of cases that were stronger with the non-dominant hand (assessed by LQ).

A specific statistical analysis was performed to calculate the statistical power of the tests. Considering a sample size of 249 participants, a type I error or alpha of 0.05 and a medium effect size of 0.30, we would obtain a statistical power of 99% for Chi-squared tests[17].

Subsamples of 25 adolescents were randomized to assess LQ reproducibility. The intra-class coefficient correlation was 0.945 (*P<0.001*).

All analyses were performed using and statistical package (IBM SPSS® 22.0, Chicago IL). The statistical significance was set up at 0.05 for all tests.

4. Results

4.1 Out-school Sport Practice

The majority of participants had OSSP, boys showed higher OSSP than girls and higher percentage of boys performed OSSP than girls (see Table 2). The rate of right and left hand dominance was similar between genders (left handedness, 22.9% in girls *vs*. 21.2% in boys).

Table 2: Sample characteristics by gender

Variables		**Girls** (n=113)			**Boys** (n=136)			**Total** (n=249)		
		Mean		SD	Mean		SD	Mean		SD
Age	(years)	15.3	±	1.5	15.5	±	1.5	15.4	±	1.5
Weight	(kg)	56.1	±	12.3	62.4	±	14.7**	59.5	±	14.0
Height	(m)	1.60	±	0.07	1.68	±	0.10**	1.65	±	0.09
BMI	(kg/m^2)	21.8	±	4.2	22.0	±	4.3	21.9	±	4.3
OSSP[a]	(%practice)	44.2%			91.9%			70.3%		

TrainingVol[b]	(min./week)	117.9	±	169.4	340.7	±	195.3**	239.6	±	214.7
Handedness[c]	(right/left)	92/21			109/27			201/48		

BMI, body mass index; OSSP, out-school sport practice.

[a], percentage of adolescents from the total sample whom performed out-school sport practice.

[b], weekly expended time on OSSP.

[c], hand dominance as self-handedness assessment by children's belief.

*, *P<0.01*; **, *P<0.001* for independent sample T-test (two-tailed).

4.1.1 Self-handedness Assessment and Hand-grip Strength

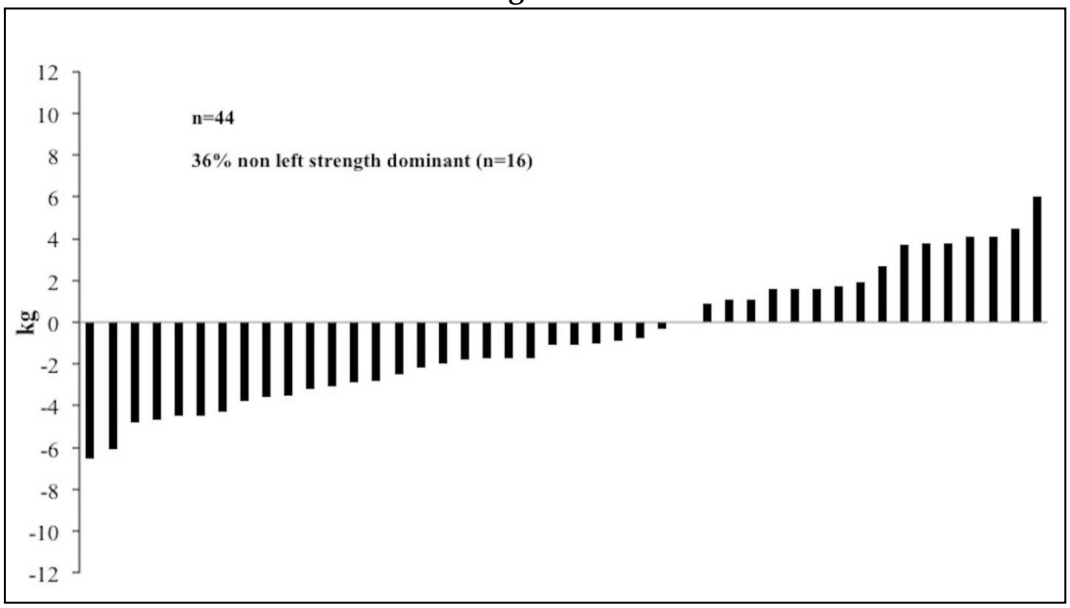
Cross tabulation between self-handedness assessment and strength dominance showed that 26.8% of the adolescents who had reported right-handedness, presented higher strength values compared to the left hand. 40% of self-reported left-handedness were stronger with the right hand, comparing with the left hand. These results confirm that, at least with strength dominance, not all of the adolescents self-reported correct hand dominance.

4.1.2 Hand-grip Strength and Handedness Assessment by LQ

Our hand-grip strength results showed that right-handedness subjects were stronger than left-handedness subjects. Nevertheless, we observed these differences for right strength only (*P>0.05* for paired sample T-test, table 3). Also, independent sample T-test confirmed that right-dominant subjects had significantly greater difference between dominant and non-dominant hand compared to left-dominant subjects (*P> 0.05*, table 3).

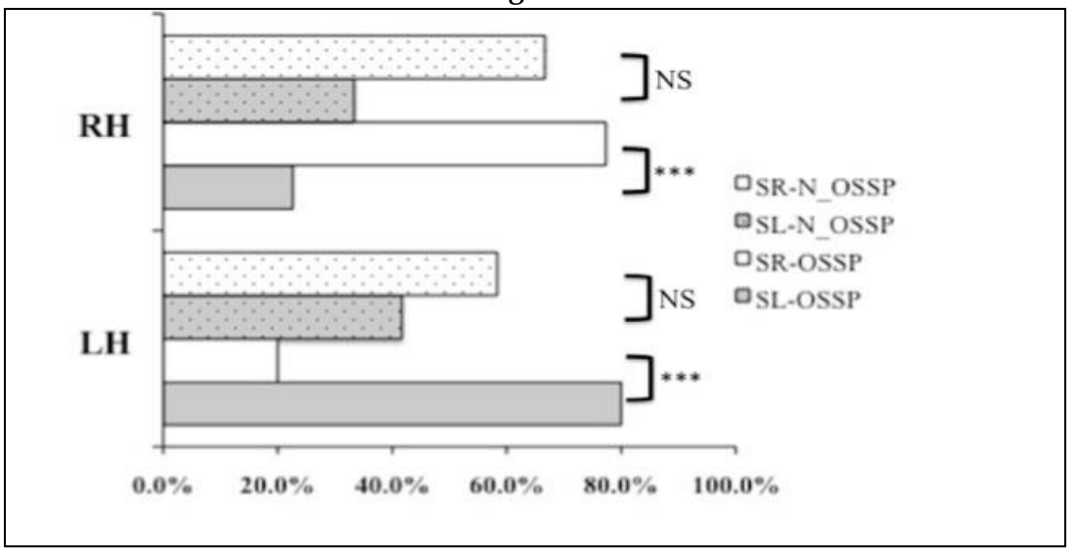
Left-handedness adolescents had less difference between right and left strength, compared to right-handedness subjects. Individual analysis showed a higher percentage of left-handedness students presented more strength with their right hand (36%) (Figure 1).

Figure 1



The greater individual variability observed for differences between right and left strength in the left-handedness group (figure 1), followed a similar pattern among right-handedness group (Figure 2), indicating that not all of the subjects with right or left dominance gripped stronger with their dominant side.

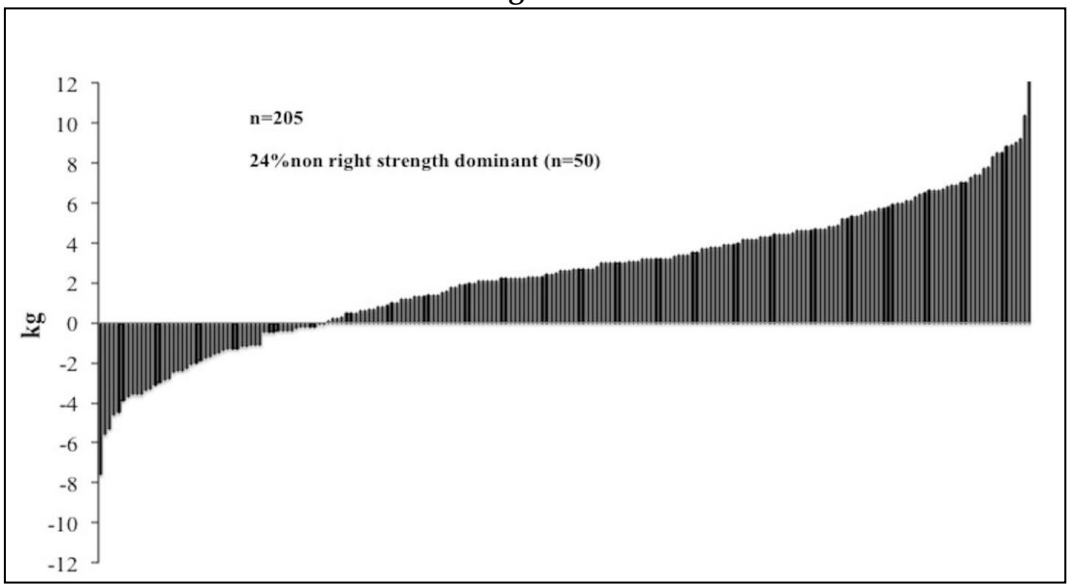
Figure 2



4.1.3 Influence of Out-School Sport Practice on Laterality Consolidation

The coincidence between strong and skillfulness hand was used as an index of LC. We found that 80% of right-handedness subjects were stronger with the right hand, and that 77.4% of left-handedness subjects were stronger with the left hand (figure 3). The higher percentage of adolescents with more strength in the non-dominant hand was observed when they had not OSSP. Chi-Squared 2x4 analysis showed a lower probability of subjects without LC among N_OSSP adolescents (*P<0.01*; Figure 3).

Figure 3



5. Discussion

The first point highlighted in this study was that the traditional method used to determine handedness in school, which is self-reported dominance, requires caution as it may not be a valid method. Our results showed a higher discrepancy between grip strength and handedness when assessed by self-reported compared to use of LC. LC is not an expensive and time-consuming method, it should be the main tool utilized for the assessment of handedness, primarily in the school setting.

Our data showed that the self-reported hand laterality was not in agreement with grip strength values. However, the LQ procedure had a higher percentage of true positive cases than self-reported assessment, for both right and left-handedness. Our results are in accordance with data from other studies[18] for subjects with LQ determined right-handedness. However, a higher percentage of left-handedness participants presented greater absolute strength in the right hand, compared to the right-handed adolescents in our investigation (64.15% *vs*. 34.4%)[18]. This discrepancy may be explained by the differences in age and/or maturation of the participants in these two investigations; for example, in the Hager-Ross's study children and adolescents ranged between 4 and 16 years, and the participants in our analysis were between 12 and 16 years old. Since it is suggested that the laterality is commonly defined after eleven years old[8]. It is plausible that the percentage of children, some below eleven years of age, without a well-defined laterality contributed to the observed difference between the LQ and grip strength, in Hager-Ross's data[18].

The primary finding of this study was that there was a higher probability of agreement between strength and handedness among adolescents who were participants in out school sport practice. To date there are no known studies exploring the influence of sport practice in the consolidation of laterality (handedness), which can be an important concern for the development of several daily skills for children and adolescents. Our results of grip strength are similar to those from Lofthus and Hansen's study of adult athlete which showed differences between right and left handedness[19]. We can speculate that sport practice can help to improve the efficiency of these daily skills, and the inverse.

In accordance with other studies[18], our results showed that left handedness subjects presented less difference between right and left isometric strength. We suggest that many left-handedness subjects have limited opportunities to develop their natural dominance. Therefore, we could not observe the theoretical strength difference between right and left-handedness individuals.

5.1 Limitations

Although the participants of this study had similar characteristics compared with others from the same region in the Alvero-Cruz JR et al.[20], we selected more self-assessed left-handedness adolescents than the original sample, in order to increase the power of

statistical analysis. As our data cannot illustrate the prevalence of left/right handedness ratio in the study region, our results of prevalence would be interpreted cautiously.

6. Recommendations

These results are important for overall physical activity promotion, physical education instruction and development, as laterality is a MSD, a cornerstone of physical activity practice. Within PE classes, instructors need to be aware of students' capabilities in order to improve their activity-related perception of competence and to improve motivation for learning specific skills that foster participation in lifelong activity[21]. This is vital in the development and maintenance of a healthy and active lifestyle. The majority of children, in developed countries, experience similar PE curriculum components and the promotion of lifelong activity is considered the universal aim of PE[22].

6.1 Human Subjects Approval Statement

The research protocol was reviewed and approved by the Ethics Committee of the Sports Medicine School, at Faculty of Medicine (Málaga, Spain). The study was developed following the ethical guidelines of the Declaration of Helsinki-Seoul, last modified in 2008.

7. Conclusion

In conclusion, the current study showed that self-assessed dominant handedness may not be the best method. In accordance with other authors[18], strong hand and skillful hand were not always correlated in our sample. We suggest the term of laterality consolidation to highlight the relationship between strength and skillful. Moreover, individual variability regarding strength differences between right and left-handed grip confirm our hypothesis that subjects with greater strength differences presented better LQ. As evidenced in our sample of adolescents, it a higher percentage of students with OSSP had better LC than those with N_OSSP, suggesting LC is partially dependent upon regular out-of school sport practice for resultant increases in hand strength, possibly due to increased specialized motor skill development

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Conflict of Interest Statement

The authors declare no conflicts of interests.

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Dr. Barrera-Exposito has been a high school physical education teacher from over 25 years for the Spanish government. He has got several appointments in universities of Spain to participate in research projects and teaching undergraduate and master courses related with physical education pedagogy and sports teaching in the adolescence.

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Appendix: Physical Activity and Laterality Questionnaires

- Original Questionnaire to Assess Laterality (written in English)

Full Name and academic year:.....
Age:..... Sex (M/F):.....
Left/Right (L/R):.....
Weight: .....
Height:..... ET(C-L-G-M-A)
Yours Father's Laterality: Left/Right
Yours Mother's Laterality: Left/Right

TASK (Where appropriate fill with X)	**Right**	**Left**	**Unknown**	**Both**
What hand do you believe you are stronger?				
Grasp a spoon				
Comb				
Bounce a ball of basketball				
Send a text message with cell phone				
Tooth brushing				
Use a board eraser				
What hand you use to open a bottle screw top?				
Writing				
What hand you use to throw a ball as far as possible?				
When using a telescope, what eye you choose to sight?				

a. In addition to the Physical Education classes, do you practice regularly any sports?
.....
Which one/s?
Sport 1: .....
Sport 2: .....
Sport 3: .....

b. How old were you when you did start to practice this/these sport/s?
Sport 1: .....
Sport 2: .....
Sport 3: .....

c. Are you enrolled in any competitive team; if yes, for how long?
.....

d. Usually, how many days per week do you have practice of each sport? Use the table below for this purpose, report the number of minutes for each sport including game days.

Weekly day	Sport 1	Sport 2	Sport 3
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

e. Do you practice any non-sport leisure activity? (For example, music, painting/drawing, help with house duties and so on). Please, indicate the activity and weekly time you spend in each of these activities.

.....

- Original Questionnaire to Assess Laterality (written in Spanish)

Cuestionario de Práctica Deportiva y Lateralidad

Nombre y Curso:.....
Edad:.....
Sexo(M/F):.....
Zurdo/Diestro (Z/D):.....
Peso: .....
Estatura:..... ET(C-L-G-M-A)
Lateralidad Padre: Zurdo-Diestro
Lateralidad Madre: Zurdo-Diestro

Acción (Señala con una X)	Derecho	Izquierdo	Indefinido	Ambos
¿Con qué mano crees que tienes más fuerza?				
Coger la cuchara para comer				
Peinarte				
Botar un balón de baloncesto				
Mandar un mensaje en el móvil				
Cepillarte los dientes				
Borrar la pizarra				
¿Con qué mano desenroscas el tapón de una botella de agua?				
Escribir				
¿Con que mano lanzarías un balón lo más lejos posible?				
Cuándo apuntas o miras por el microscopio ¿qué ojo dejas abierto?				

a. ¿Practicas deporte además de las horas de educación física?
.....
¿Cuál o cuáles?
Deporte 1: .....
Deporte 2 : .....
Deporte 3: .....

b. ¿A qué edad comenzaste a realizar deporte?.....
¿Cuántos años llevas federado en cada deporte, si lo estás?
.....

c. Normalmente, ¿cuántos días practicas por semana en cada uno de los deportes? (Escribe debajo del nombre del deporte, en el día de la semana que corresponda, y los minutos que juegas (incluye entrenamientos y partidos si los hubiera).

Día de la semana	**Deporte 1**	**Deporte 2**	**Deporte 3**
Lunes			
Martes			
Miércoles			
Jueves			
Viernes			
Sábado			
Domingo			

d. ¿Realizas alguna actividad no deportiva regularmente? (Por ejemplo, musicales, pintura, ayudar en algún trabajo, etc.). Indica el tiempo que empleas en cada tarea:
.....