

Mayorga-Vega, D.; Merino-Marban, R. y García-Romero, J.C. (2015). Validez del test sit-and-reach con flexión plantar en niños de 10-12 años / Validity of sit-and-reach with plantar flexion test in children aged 10-12 years. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 15 (59) pp. 577-591.  
[Http://cdeporte.rediris.es/revista/revista59/artvalidez602.htm](http://cdeporte.rediris.es/revista/revista59/artvalidez602.htm)  
DOI: <http://dx.doi.org/10.15366/rimcafd2015.59.011>

## ORIGINAL

### VALIDITY OF SIT-AND-REACH WITH PLANTAR FLEXION TEST IN CHILDREN AGED 10-12 YEARS

### VALIDEZ DEL TEST SIT-AND-REACH CON FLEXIÓN PLANTAR EN NIÑOS DE 10-12 AÑOS

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#### ACKNOWLEDGEMENTS

The first author is supported by grant of the University Professor Training program from the Spanish Ministry of Education, Culture and Sport (AP2010-5905).

**Código UNESCO / UNESCO code:** 2411 Fisiología Humana / Human physiology

**Clasificación Consejo de Europa / Council of Europe classification:** 11. Medicina del Deporte / Sport Medicine

**Recibido** 23 de mayo de 2012 **Received** May 23, 2012

**Aceptado** 21 de marzo de 2013 **Accepted** March 21, 2013

#### ABSTRACT

The main purpose of this study was to examine the criterion-related validity of classic sit-and-reach (CSR) and sit-and-reach with plantar flexion (SRF) tests for estimating hamstring extensibility in children. A total of 72 students (40 boys and 32 girls) aged 10-12 years performed the lineal tests CSR and SRF, and the criteria measure passive straight-leg raise test. Pearson's correlation (r) results showed moderate values of association between CSR and SRF with hamstring extensibility ( $r = 0.71$  and  $r = 0.74$ ,  $ps < 0.01$ , respectively). Criterion-related validity values found for SRF were greater than for the CSR, except for

the girls where the values were similar. The findings of this study suggest that the assessment of hamstring flexibility by sit-and-reach test should be performed allowing plantar flexion.

**KEY WORDS:** Criterion-related validity, Flexibility, Hamstring extensibility, Passive straight-leg raise test, Classic sit-and-reach test, Field test, Primary Education.

## RESUMEN

El principal objetivo del presente estudio fue examinar la validez de criterio de los tests sit-and-reach clásico (SRC) y sit-and-reach con flexión plantar (SRF) para estimar la extensibilidad de la musculatura isquiosural en niños. Un total de 72 escolares (40 niños y 32 niñas) de 10-12 años de edad realizaron los tests lineales SRC y SRF, y el test criterio de medida elevación pasiva de la pierna recta. Los resultados de la correlación de Pearson ( $r$ ) mostraron moderados valores de asociación de los tests SRC y SRF con la extensibilidad isquiosural ( $r = 0,71$  y  $r = 0,74$ ,  $ps < 0,01$ , respectivamente). Los valores de validez de criterio encontrados para el SRF fueron mayores que para el SRC, excepto para las niñas en el que fueron similares. Los hallazgos del presente estudio sugieren que la evaluación de la extensibilidad de la musculatura isquiosural mediante el test sit-and-reach debería realizarse permitiendo la flexión plantar.

**PALABRAS CLAVE:** Validez de criterio, Flexibilidad, Extensibilidad isquiosural, Elevación pasiva de la pierna recta, Sit-and-reach clásico, Test de campo, Educación Primaria.

## INTRODUCTION

Flexibility is a physical fitness component that has been widely related to health (Bouchard & Sheppard, 1994). The lack of hamstring muscles extensibility conditions a decrease of pelvic mobility that leads to an invariable biomechanical change in the pressure distribution in the spine (Da Silva Días & Gómez-Conesa, 2008). Hence, poor hamstring flexibility has been associated with postural deviations, gait limitations, increased risk of falls, and susceptibility to musculoskeletal injuries (Erkula, Demirkan, Kilic, & Kiter, 2002; Funk, Swank, Adams, & Tredo, 2001; Jones, Rikli, Max, & Noffal, 1998). Moreover, among young people a good flexibility in the hips seems to contribute to the decrease of the risk of low back pain (Feldman, Shrier, Rossignol, & Abenhaim, 2001; Jones, Stratton, Reilly, & Unnithan, 2005; Kujala, Salminen, Taimela, Oksanen, & Jaakkola, 1992; Sjölie, 2004) and neck tension (Mikkelsen et al., 2006).

The assessment of hamstring muscle extensibility can be validly measured through angular test. Among them, the passive straight-leg raise test (PSLR) has been considered as one of the criteria measure most appropriate for children (Castro-Piñero et al., 2009b). However, the PSLR is a sensitive test that requires adequate technical skills, dilated time, relatively expensive

instruments and at least two testers for objective measurement (López Miñarro et al., 2008b). Therefore, it seems that its use is not feasible especially in school setting and population studies. However, unlike angular tests, the lineal tests have a number of advantages: these tests have a simple procedure, are easy to administer, require minimal skills training for their application (Castro-Piñero et al., 2009b) and the equipment necessary to perform them is very affordable, allowing the evaluation of a large number of people in a short space of time (López Miñarro, Sainz de Baranda Andújar, Yuste Lucas, & Rodríguez, 2008c).

Traditionally, the lineal test sit-and-reach (SR), originally designed by Wells and Dillon (1952), has been included in the most physical fitness test batteries for children in order to assess flexibility (Castro-Piñero et al., 2009a). The most common interpretation of SR test results is that individuals with better scores possess a higher degree of hamstring flexibility than those with lower scores (Arregui Eraña & Martínez de Haro, 2001; Bandy, Irion, & Briggler, 1998; Hoeger, Hopkins, Button, & Palmer, 1990). However, the validity of the classic sit-and-reach test (CSR), as well as its different modifications, for estimating the hamstring muscle extensibility among young people has been widely questioned (Castro-Piñero et al., 2009b; Garcia, 1995; Hartman & Looney, 2003; Kanbur, Düzgün, Derman, & Baltaci, 2005, López-Miñarro et al., 2008a).

It has been suggested that the evaluation of the flexibility through the SR test might be influenced by the position of the ankles (Holt, Pelham, & Burke, 1999; Liemohn, Martin, & Pariser, 1997; Rubinfeld, Wygand, & Otto, 2002; Strickland, Price, & Gross-Sampson, 2003). To solve this methodological “problem”, current studies carried out with adults have suggested incorporating a door in the front of the SR box that allows to perform a plantar flexion (Cardoso, Azevedo, Cassano, Kawano, & Âmbar, 2007; Kawano et al., 2010), eliminating in this way the bias produced by the influence of the ankles position as happened in the CSR test. In this sense, Kawano et al. (2010) found higher values when the SR was performed with a plantar flexion (door opened) than when it was carried out with the ankle at 90° as in its classic version. Unfortunately, this study did not address the important question of the validity, as well as no studies have been found about the criterion-related validity of the SR with plantar flexion among children. Consequently, the purpose of this study was to examine the criterion-related validity of the sit-and-reach with plantar flexion (SRF) and classic sit-and-reach tests for estimating hamstring extensibility in children 10-12 years old.

## **MATERIAL AND METHODS**

### **Participants**

A total of 72 students aged 10-12 years participated in this study. The participants were boys (n = 40) and girls (n = 32) attending 5th and 6th grade of a primary education school in Malaga (Spain). Inclusion criteria followed were: a) absence of musculoskeletal limitations; b) absence of spinal pain, c) and/ or

absence of hip pain that might limit the tests performance (López-Miñarro et al., 2008c). Children and their parents or legal guardians were fully informed about the nature and purpose of the study. The informed consent document was obtained from their parents or legal guardians. The study was approved by the Ethics Committee of the University of Malaga.

### Testing procedure

*Classic sit-and-reach test and sit-and-reach with plantar flexion test.* The tests were administered using a wooden box of 30.5 cm x 30.5 cm x 30.5 cm with a ruler at the top (the score 23 cm corresponded to the tangent of the feet; accuracy 0.1 cm). The box had a door 27 cm x 27 cm in the front side where the participant placed the soles of his/her feet, allowing the plantar flexion when the door was opened. At the beginning of the test, each child stood in front of the box, sat with his/ her hips flexed, knees extended and both hands on the top of the ruler. The feet were placed to the width of the hips, ankles at 90° (when the door was closed) for the CSR test and with a plantar flexion (when the door was opened) for the SRF test (Cardoso et al., 2007; Kawano et al., 2010).

The hands with the fingers extended were placed parallel to the shoulders width, to avoid the influence of the scapular flexibility (Hopkins & Hoeger, 1992). To avoid a further influence of the trunk flexibility, the head was placed in a neutral position (Smith & Miller, 1985; Tardie, 1993). The knees were fixed in extension with the help of the tester. From this position, the child had to bend the trunk forward slowly and progressively (no rebounds) in order to reach the greatest possible distance. In the maximum flexion position, the participant had to remain still for at least two seconds. The average of two trials was recorded for subsequent statistical analysis (Figure 1) (Consejo de Europa, Comité para el Desarrollo del Deporte, 1992).

*Passive straight-leg raise test (PSLR).* The criterion measure of hamstring flexibility was determined by executing the PSLR test. This test was selected because of its widespread acceptance as the criterion measure of hamstring extensibility (Castro-Piñero et al., 2009b; Hartman & Looney, 2003; Kanbur et al., 2005). With the participant laid supine, the participant's evaluated leg was passively raised into hip flexion with the knee extended, slowly and progressively. To measure the angle, the tester placed an inclinometer (AcuAngle®, Japan) on the distal third of the tibia anterior side, placing it at zero degrees in the starting position. The same tester placed his free hand over the participant's knee to keep it straight. Furthermore, an auxiliary tester kept the contralateral leg straight into contact with the surface of the mat, avoiding pelvis external rotation and preventing posterior pelvic tilt (Figure 2) (Ayala & Sainz de Baranda, 2008; Sainz de Baranda & Ayala, 2010).



**Figure 1.** a) Classic sit-and-reach test (door closed), b) Sit-and-reach with plantar flexion test (door opened)

The end point of the leg raise was determined by the tester's perception of a firm resistance, and/ or palpation by the auxiliary tester of the initiation of pelvis rotation. The criterion score of the hip flexion range of motion was the maximum angle recorded by the inclinometer at the point of maximum hip flexion. This measurement was performed twice separately and alternately in both legs. Hamstring extensibility score was determined as the average of the two measurements of each leg (Ayala & Sainz de Baranda, 2008; Sainz de Baranda & Ayala, 2010).



Figure 2. Passive straight-leg raise test

## Procedure

Previously we conducted a pilot study with ten elementary students to estimate the reliability of the flexibility tests administered. The students' evaluation was conducted during Physical Education classes. All tests were performed during the same session for each student. Furthermore, to avoid some bias due to diurnal variations of flexibility (Manire, Kipp, Spencer, & Swank, 2010), all the participants were evaluated during the same period of the day and under the same environmental conditions.

The participants were examined in sportswear and barefoot. A week before, a familiarization session was carried out for children in order to learn about the protocol of the tests, and then children performed two trials of each test. Before evaluation, all participants performed a standardized five-minute warm-up of running at low intensity. Immediately after that, the children performed randomly the CSR, SRF, and PSLR tests. Students had a passive rest time of 15 minutes between tests, as it has been considered sufficient time to avoid the influence of repeated measures (Depino, Webright, & Arnold, 2000). Each test was administered by the same researcher for all students.

## Statistical analysis

Descriptive statistics (means and standard deviations) of age, height, body mass, body mass index, and flexibility tests values were calculated. Prior to conducting the analyses, the Kolmogorov-Smirnov test was used to assess the normality of the data. Because all variables followed a normal distribution, parametric tests were used for statistical analysis. Student's t test for independent samples was calculated to compare the mean values between boys and girls. Criterion-related validity was calculated using the Pearson

correlation coefficient ( $r$ ) between CSR and SRF lineal tests, and PSLR test for each leg separately, as well as for the average of both legs (Thomas & Nelson, 2007).

In addition, unstandardized multiple regression coefficients ( $\beta$ ), 95% confidence intervals (CI), standard error (SE), and coefficients of determination ( $R^2$ ) also were used to examine the association of CSR and SRF tests with hamstring extensibility (Mahar & Rowe, 2008). Intraclass correlation coefficient of two-way ANOVA ( $ICC_{3,k}$ ) was used to estimate the reliability of the pilot study measures (Shrout & Fleiss, 1979), which was accompanied by the 95% confidence interval (CI) (Baumgartner & Chung, 2001). All statistical analyses were performed using the SPSS 15.0 for Windows (SPSS® Inc., Chicago, IL). The statistical significance level was set at  $p < 0.05$ .

## RESULTS

The characteristics of the sample (mean  $\pm$  standard deviation) are in Table 1. The results of the Student's  $t$  test for independent samples showed that girls had statistically significant higher scores in all flexibility measures than boys ( $p \leq 0.023$ ), except for the SRF in which the difference was only marginally significant ( $p = 0.060$ ). In addition, the girls showed statistically significant greater values of height than the boys ( $p = 0.008$ ).

**Table 1.** Characteristics of study sample (mean  $\pm$  standard deviation)

Measures	Total (n = 72)	Boys (n = 40)	Girls (n = 32)
Age (years)	10.86 $\pm$ 0.70	10.85 $\pm$ 0.74	10.88 $\pm$ 0.66
Height (cm)	148.61 $\pm$ 8.90	146.15 $\pm$ 7.42	151.69 $\pm$ 9.73**
Body mass (kg)	47.31 $\pm$ 12.30	45.45 $\pm$ 11.81	49.63 $\pm$ 12.69
BMI (kg/m <sup>2</sup> )	21.17 $\pm$ 4.01	21.03 $\pm$ 4.05	21.35 $\pm$ 4.02
CSR (cm)	23.91 $\pm$ 6.45	22.38 $\pm$ 5.85	25.82 $\pm$ 6.74*
SRF (cm)	28.81 $\pm$ 6.00	27.63 $\pm$ 5.52	30.30 $\pm$ 6.34
PSLR left (°)	79.08 $\pm$ 8.62	76.95 $\pm$ 7.25	81.75 $\pm$ 9.54*
PSLR right (°)	81.92 $\pm$ 10.47	79.15 $\pm$ 9.23	85.38 $\pm$ 11.04*
PSLR mean (°)	80.50 $\pm$ 9.27	78.05 $\pm$ 7.99	83.56 $\pm$ 9.95*

*Note.* BMI, Body mass index; CSR, classic sit-and-reach test; SRF, sit-and-reach with plantar flexion test; PSLR, passive straight-leg raise test.

\*  $p < 0.05$ , \*\*  $p < 0.01$  for differences between gender.

Pearson's bivariate correlation analyses ( $r$ ) between the lineal tests and the PSLR test for the whole sample, as well as for boys and girls separately, are in Table 2. The results showed moderate validity values for both CSR and SRF tests ( $p < 0.01$ ). However, for the whole sample and the boys separately the validity values were higher for the SRF test than for the CSR test.

**Table 2.** Pearson´s correlation coefficient (r) between the values of the classic sit-and-reach and sit-and-reach with plantar flexion tests with the hamstring extensibility

Measures	Total (n = 72)		Boys (n = 40)		Girls (n = 32)	
	CSR	SRF	CSR	SRF	CSR	SRF
PSLR left	0.71*	0.73*	0.64*	0.71*	0.72*	0.73*
PSLR right	0.68*	0.70*	0.62*	0.68*	0.68*	0.67*
PSLR mean	0.71*	0.74*	0.65*	0.72*	0.72*	0.72*

Note. CSR, classic sit-and-reach test; SRF, sit-and-reach with plantar flexion test; PSLR, passive straight-leg raise test.

\* p < 0.01

The Table 3 shows the multiple regression analysis examining the association between CSR and SRF tests with PSLR test for the whole sample, as well as for boys and girls separately. The CSR and SRF tests were statistically significant associated with hamstring extensibility both in the whole sample, and in boys and girls separately (p < 0.001). However, a greater association was found for the SRF than SRC when data were analyzed for the whole sample (R<sup>2</sup> = 0.540 vs. R<sup>2</sup> = 0.505, p < 0.001) and for boys (R<sup>2</sup> = 0.512 vs. R<sup>2</sup> = 0.418; p < 0.001). In the girls a similar association was found in both lineal tests (CSR, R<sup>2</sup> = 0.521, p < 0.001; SRF, R<sup>2</sup> = 0.520, p < 0.001).

**Table 3.** Unstandardized multiple regression coefficients (β), 95% confidence intervals (95% CI), standard error (SE), and coefficients of determination (R<sup>2</sup>) examining the association of classic sit-and-reach and sit-and-reach with plantar flexion with hamstring extensibility

Measures	β	95% CI	SE	R <sup>2</sup>	p
Total (n = 72)					
CSR	1.021	0.780-1.262	0.121	0.505	< 0.001
SRF	1.134	0.885-1.384	0.125	0.540	< 0.001
Boys (n = 40)					
CSR	0.884	0.541-1.226	0.169	0.418	< 0.001
SRF	1.037	0.705-1.369	0.164	0.512	< 0.001
Girls (n = 32)					
CSR	1.064	0.683-1.445	0.187	0.521	< 0.001
SRF	1.133	0.727-1.538	0.199	0.520	< 0.001

Note. CSR, classic sit-and-reach test; SRF, sit-and-reach with plantar flexion test

Ten elementary students (age 11.00 ± 0.47 years; height 154.40 ± 4.39 cm; body mass 43.00 ± 9.38 kg; body mass index 17.92 ± 3.01 kg/m<sup>2</sup>) participated in a pilot study to estimate the reliability of flexibility measures administered. The results of ICC<sub>3,k</sub> (95% CI) showed high reliability values for each one of the tests administered in this study [CSR, 0.97 (0.95-0.98); SRF, 0.98 (0.97-0.99); PSLR left, 0.99 (0.97-1.00); PSLR right, 0.99 (0.95-1.00)].



## DISCUSSION

The main purpose of this study was to examine the criterion-related validity of the CSR and SRF lineal tests for estimating hamstring extensibility in children 10-12 years old. The correlation results showed that the CSR and SRF tests were moderately associated with hamstring extensibility. In this line, previous studies with young people found from very low to moderate values of criterion-related validity of the CSR test for estimating hamstring extensibility ( $r = 0.38-0.81$ ) (Castro-Piñero et al., 2009b; García, 1995; Hartman & Looney, 2003; Kanbur et al., 2005; López-Miñarro et al., 2008a). In addition, similar values were found when the validity of different modifications of CSR test was examined among young people ( $r = 0.28-0.69$ ) (Castro-Piñero et al., 2009b; Hartman & Looney, 2003; Patterson, Wiksten, Ray, Flanders, & Sanphy, 1996). Furthermore, in previous studies with adults values ranging from low to moderate were found for the CSR and its different modifications (Baltaci, Tunay, Besler, & Gerçeker, 2003; Chung & Yuen, 1999; Hui, Yuen, Morrow, & Jackson, 1999; Hui & Yuen, 2000; Jones et al., 1998; Lemmink, Kemper, De Greef, Rispens, & Stevens, 2003; López-Miñarro et al., 2008c; López-Miñarro, Sainz de Baranda Andújar, & Rodríguez-García, 2009; López-Miñarro, Alacid, Muyor, & López, 2010a; López-Miñarro, García Ibarra, & Rodríguez García, 2010b; López-Miñarro, Muyor, & Alacid, 2011). Unfortunately, previous studies that address the criterion-related validity of the SRF with which to compare the results of the current study have not been found.

The main finding obtained in this study was that the SRF test is a measure method of hamstring extensibility more valid than the CSR test. Although no previous studies have been found that address the validity of the SRF test, it has been found a few studies that compared the validity of the CSR test with other modifications that, presumably, should be more valid than the classic version. In studies with young people, Castro-Piñero et al. (2009b) examined the validity values of the modified SR and CSR tests. These authors starting from the above premise postulated by Hoeger et al. (1990), that the incorporation of a finger-to-box distance removed the bias for proportional differences between legs and arms, presupposed that better validity values could be found. However, Castro-Piñero et al. (2009b) found that the modified SR validity showed lower validity values than CSR for both children (modified SR,  $r = 0.34$ , CSR,  $r = 0.38$ ) and adolescents (modified SR,  $r = 0.26$ ; CSR,  $r = 0.38$ ). In this line, in previous studies carried out with adults the CSR had higher validity values than the modified SR (Chung & Yuen, 1999; Lemmink et al., 2003; López-Miñarro et al., 2010a, 2010b).

Meanwhile, Hartman and Looney (2003) estimated the validity of the Back-saver SR and the CSR tests in children aged 6 to 12 years. The Back-saver SR is a test that was created to protect the back from the tension that occurs when the individual performs a trunk bending as in the CSR (Cooper Institute for Aerobics Research, 2004). The results of the Hartman and Looney's (2003) study revealed higher values for the Back-saver SR among the boys, while for the girls were lower. In studies carried out with adults better values of validity of

hamstring extensibility for the Back-saver SR than for the CSR in both men and women were found (Baltaci et al., 2009; Hui et al., 1999; Hui & Yuen, 2000; Jones et al., 1998; López-Miñarro et al., 2008c, 2009, 2010a). Moreover, in other studies with adult people uneven results for the Chair SR (Baltaci et al., 2009; Jones et al., 1998) and the V SR tests (Hui et al., 1999; Hui & Yuen, 2000; López-Miñarro et al., 2010a) were found. Hence, the current study is one of the first to find better values of validity in a modification of CSR among youth.

When values were analyzed separately by gender, a greater association was also found for SRF test among boys. However, in girls there was no difference in the values of criterion-related validity between SRF and CSR tests. Furthermore, the association values of the CSR test were higher for girls than boys, whereas no difference was found between genders for the SRF test. The most studies with young people do not differentiate their results by gender. Only four studies were found that differentiate by gender (Garcia, 1995; Hartman & Looney, 2003; López-Miñarro et al., 2008a; Patterson et al., 1996). In the findings of these studies we can see how the validity between boys and girls are similar, being slight variations. Also, some of the studies that combine both genders performed a preliminary analysis in which their authors found no gender interaction (Castro-Piñero et al., 2009b), the reason why they joined genders for further statistical analysis. Among adults likewise values are similar between men and women, with slight variations in both directions (Hui et al., 1999; Hui & Yuen, 2000; Jones et al., 1998; Lemmink et al., 2003; López-Miñarro et al., 2008c, 2009, 2010a, 2010b).

Finally, regression analysis results indicated that both the CSR and the SRF tests were significantly associated with hamstring extensibility. However, the variance explained was relatively moderate. These results suggest that, in addition to the ankle position, other variables must also affect the values of the lineal tests. In this regard, recently Chillón et al. (2010) in their study with adolescents concluded that the main variance explained in the Back-saver SR was in the hips flexibility ( $R^2 = 0.42$ ). However, these authors also found that the flexibility of the spine accounted additionally for 34% of the variance. In conclusion, the findings of this study suggest that the assessment of hamstring muscle extensibility by the SR test should be performed allowing the plantar flexion. In addition, future research should further study the field tests that would allow a more valid assessment of hamstring muscle extensibility.

## CONCLUSIONS

The criterion-related validity of sit-and-reach with plantar flexion test to estimate hamstring extensibility is higher than the classic sit-and-reach test among children 10-12 years old. The validity values found among children of 10-12 years old for the sit-and-reach with plantar flexion and classic sit-and-reach tests are moderate. The findings of this study suggest that the assessment of hamstring muscle extensibility by the sit-and-reach test should be performed allowing the plantar flexion.

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