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# Effect of Pilates Method on muscular trunk endurance and hamstring extensibility in adolescents during twelve weeks training and detraining

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Physical education
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A B S T R A C T

*Background:* Thoracic hyperkyphosis and lumbar hyperlordosis have been associated with low values of flexibility in the hamstring muscle and endurance of the trunk musculature. These are areas that are worked using the Pilates Method (PM), however, there are only two studies that assess its effect on these variables in adolescence, and none that measure the retention time of the acquired improvements. The main objective of this research was to assess the effect of 10 min of adapted exercise program from PM in a Physical Education class (PE) for 12 weeks, on trunk muscle endurance and hamstring flexibility, and to evaluate the retention of resulting changes.

*Methods:* The sample consisted of 441 adolescents (age = 13.9 ± 1.3 years). The experimental group (EG) performed two weekly 10-min sessions of PM for 12 weeks. The control group (CG) performed its usual sessions of PE. The endurance of the trunk flexor muscles and trunk extensor muscles, toe touch test (TT), bench trunk curl test (BTC) and the Biering-Sörensen test (SOR), were used to evaluate hamstring flexibility, before application of the program, at the end, 12 weeks later.

*Results:* A significant improvement was found in the EG for all variables analyzed, with an average improvement of 9.37 repetitions in the BTC test, 19.4 s in the SOR test and 2.75 in the TT test. The CG did not show significant changes. The EG's improvements were retained 12 weeks later, except in the SOR test.

*Conclusion:* The inclusion of 10 min of adapted exercise program from PM in PE classes, for two weekly sessions over 12 weeks, produces improvements in trunk muscle endurance and hamstring flexibility, and these gains are retained in the flexor and hamstring muscles 12 weeks later.



## 1. Introduction

Studies show a high prevalence of spinal misalignment (Sedrez et al., 2015; Vieira et al., 2016) and a lack of spine stability in the adolescent population (Feng et al., 2017; Johnson et al., 2009). Between 32% and 50% of thoracic hyperkyphosis and between 37% and 43% of lumbar hyperlordosis has been found in schoolchildren (Sedrez et al., 2015; Vieira et al., 2016). This could contribute to the development of various pathologies of the spine, as well as to the onset of back pain (Borghuis et al., 2008; Zazulak et al., 2008) and to a decrease in perceived functional capacity and quality of life by adolescents (Macedo et al., 2015). A sagittal disposition outside the ranges of normality increases the probability of suffering pathologies such as spondylolisthesis, disc hernias and certain lesions of acute and chronic characters (Santonja et al., 2000). The origin of these pathologies could be multifactorial. Thoracic hyperkyphosis when standing, as well as an inversion to kyphosis of the lumbar curvature associated with a pelvic retroversion in positions of maximum trunk flexion with extended knees, are associated with low values of flexibility in the hamstring musculature (Andújar et al., 1996; Ferrer, 1998). Lumbar hyperlordosis is related to a shortening of the psoas-iliacus, which causes a pelvic anteversion, generating a greater overload on the posterior part of the spine (Santonja and Pastor, 2003). This misalignment has also been associated with low values of endurance in the paravertebral and trunk muscles (Moore et al., 2013), and with a relationship between the relaxation of the muscles of the anterior rectus abdominis and

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the presence of hyperlordotic lumbar curves (Andreotti and Mauri, 1989).

In this sense, the internal oblique and the transverse musculature increase the intra-abdominal pressure through the thoracolumbar fascia (McGill, 2002). In addition, together with the multifidus and thoracic lumbar iliocostal muscles influence functional stability of the spine (Chaitow and Delany, 2002; Danneels et al., 2000). In adolescents, back pain has been related to mobility of the hips and lumbar region in the sagittal plane, trunk flexion and lateral rachis inclination, endurance of the trunk flexor-extensor muscles (Mikkelsson et al., 2006; Johnson et al., 2009) and lumbar mobility (Feng et al., 2017).

Periods of growth are time soft great vulnerability for the spine (Grimmer and Williams, 2000), and it seems clear that exercise improves spine stabilization in adolescents. The Pilates Method (PM) is one exercise program for the improvement of these parameters. This technique focuses on improving control by stretching and strengthening the muscles, improving flexibility, strength, coordination and balance (Adamany, 2006). Trunk stability and posture are the focus of PM, and all exercises begin with activation of the abdominal and deep lumbar musculature (transverse abdominal, internal oblique and lumbar multifidus) (Sapsford et al., 2001), all of which are especially related to trunk stability (Chaitow and Delany, 2002).

Several systematic review found that traditional (Byrnes et al., 2018; Cruz-Ferreira et al., 2011) and adapted (Cruz-Ferreira et al., 2011) MP reduced pain and disability (Byrnes et al., 2018), and improve flexibility and muscular endurance (Cruz-Ferreira et al., 2011).

Although various investigations provide positive results regarding the adult population (Byrnes et al., 2018; Kliziene et al., 2016), there is only one investigation that assesses the effect of the systematic practice of exercises adapted from PM on trunk endurance (González-Gálvez et al., 2014), and two that assess hamstring flexibility, in adolescents (González-Gálvez et al. 2014, 2015), and none analyzed the time that the acquired improvements are retained.

On the other hand, although this study shows improvement (González-Gálvez et al. 2014, 2015), it is difficult to implement in school because Physical Education course have to treat several topics and they cannot use the all session in these exercises. Therefore, taking just a little part of the lesson to perform these exercises may be a good solution. Several studies apply a systematic exercise two time per weeks, from 3 to 15 min, from 6 to 32 weeks of specific exercise in Physical Education lesson and show improvement in trunk endurance (Allen et al., 2014; Durall et al., 2009) and hamstring extensibility (Bohajar-Lax et al., 2015; Mayorga-Vega et al., 2014a, 2014b; Moreira et al., 2012; Rodríguez et al., 2008; Sainz de Baranda, 2009; Sainz de Baranda et al., 2006; Sánchez-Rivas et al., 2014); however this duration of the session has not been investigated with exercise adapted from MP.

The objective of this research was therefore to assess the effect of a 12-week of exercises adapted program from PM, with a frequency of two sessions of 10 min per week with in Physical Education classes, on the endurance of the trunk musculature and hamstring flexibility in adolescents; and to evaluate the retention of the changes produced after the application of the program.

## 2. Methods

### 2.1. Participants

Four hundred and forty-one teenagers (male sex: MS = 232; female sex: FS = 209), between 12 and 17 years old (average age: 13.9 ± 1.3 years old) participated in this study. They were all students at a high school in the Region of Murcia, Spain. Participants were randomized into an experimental group (EG, n = 256) and a control group (CG, n = 185). The criteria for inclusion were: a) being physically active in Physical Education sessions and participating in ordinary assessments; b) being healthy, without musculoskeletal, neurological, cardiological, metabolic or rheumatic illness; and c) not missing more than one program session (91.7% attendance). An Institutional Ethical Committee of Catholic University of Murcia approved the study. The parents or tutors of the children, and the subjects who participated in this study were informed of the procedures and signed a consent form before the measurements were made.

### 2.2. Procedures

The EG took part in an exercise program over 12 weeks (twice per week). The program was performedduring 12 weeks because it was developed in a full quarter without interruption to avoid the effect of the Christmas, Easter or summer holidays which could influence the results and because the most of the studies that assess detraining effect have durations between 8 and 12 weeks (Mujika and Padilla, 2000; Tsolakis et al., 2004; Tucci et al., 1991). The program consisted in two sessions/week because most of the similar programs at school performance consist of two sessions per week (Durall et al., 2009; González-Gálvez et al. 2014, 2015; Moreira et al., 2012), and because the Physical Education course has a frequency of 2 sessions per week.

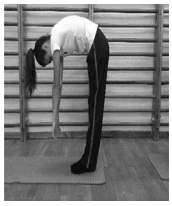
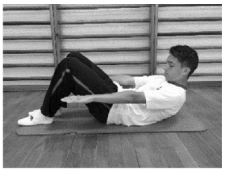
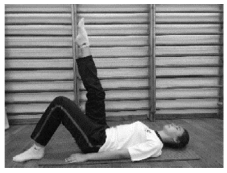
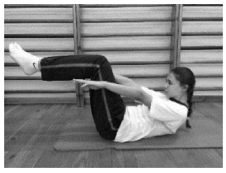
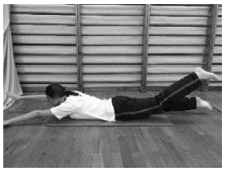
The program focused on four exercises adapted from PM, at the end section of the Physical Education sessions, for a total duration of 10 min. The Physical Education teacher taught all the EG sessionsIt focused on four exercises for each month, with the exercises increasing in difficulty. The four exercises selected were chosen for their particular movement and their specific muscle activation. It included one exercise focused on trunk flexor endurance, one exercise focused on turn or rotation trunk endurance, one exercise for the endurance of the trunk extensor musculature, and one for hamstring extensibility, in order to select a complete program from exercise adapted from MP. Exercise name, picture, set and repetition for each selected exercise in each month are shown in Table 1, following the indication for adapted Pilates (González-Gálvez and Sainz de Baranda, 2011; Paredes, 2007). The series indicated were carried out for each side in unilateral exercises. All exercises were selected from original Pilates (month 1: rolling back, one leg stretch, shoulder bridge and the push up; month 2: the hundred, one leg stretch, the leg pull and one leg circle; month 3: roll up, scissors, swimming and one leg stretch) (González-Gálvez and Sainz de Baranda, 2011; Pilates and Miller, 1945; Pilates, 1934) and then were adapted to the specific characteristics of the population (González-Gálvez and Sainz de Baranda, 2011; Paredes, 2007).

PM principles (concentration, center, breathing, control, precision and fluency) (Adamany, 2006; Mallery et al., 2003) were included gradually with the intention of a better comprehension. Each principle was explained in each session. After six session all the principles had been included.

The CG took part in their usual Physical Education lesson at school, without including the PM specific exercise, but adding some games, stretching and relaxation exercises at the end.

Measurements were taken before (pre-test), after the 12-week program intervention (post-test) and 12 weeks after finishing the PM program (re-test). All the measurements were performed by the same researchers in a single session, between 10:00 and 14:00 hours. No warm-up or stretching exercises were performed by the participants before the test measurements. The participants were examined barefoot. The measurements were performed in a

**Table 1**
Pilates Method exercise program.

| | | | |
|---|---|---|---|
| Month 1 | | | |
|  |  |  |  |
| a) Rolling back (2 set x 6 rep) | b) One leg stretch modified without movement of upper part of the body (2 set x 12 rep) | c) Shoulder Bridge (6 rep) | d) The push up modified to first part of the movement- Roll down (4 rep) |
| Month 2 | | | |
|  |  |  |  |
| a) The hundred modified with feet on floor (1 set x 100 rep) | b) One leg stretch (2 set x 12 rep) | c) The leg-pull front modified to superman (2 set x 12 rep) | d) One leg circle (2 set x 5 rep) |
| Month 3 | | | |
|  |  |  |  |
| a) Roll Up modified to half roll up with table position (1 set x 12 rep) | b) Scissors modified (2 set x 12 rep) | c) Swimming (3 set x 15 seg) | d) One leg stretch (3 set x 8 rep) |

random order. The laboratory temperature was standardized at 24 °C. There was a 5-min rest between measures. In order to stablish the reliability of the examiners before the measurement, a double-blind study was performed using the assessment protocol with 30 participants, and an intraclass correlation coefficient higher than 95% coefficient interval was obtained.

### 2.3. Anthropometry variables

Body mass was measured using a SECA 762 scale (SECA, Germany) and height using a GPM anthropometer (Siber-Hegner, Switzerland). BMI ($kg/m^2$) was calculated [body mass (kg)/stretch stature $(m)^2$].

### 2.4. Bench trunk curl test (BTC)

The Bench trunk curl test (BTC) was conducted to evaluate the endurance of the trunk flexor musculature. The test has been demonstrated as safe, protecting the back and isolating the abdominal musculature. Its reliability and validity has been demonstrated (Knudson, 2001). The subjects were placed in a supine position with their lower extremities resting on a chair 0.46 m high, with90° hip and knees flexion. Arms were crossed over the chest and hands grasped the elbow of the opposite arm (see Fig. 1). The participants curled their trunk so that their forearms touched the front of their thighs, and then uncurled so their scapula blades touched the floor again (see Fig. 2). Subjects did the maximum number of repetitions in 120 seg. The number of complete cycles was counted (Knudson, 2001).

**Fig. 1.** Bench trunk curl test set position.

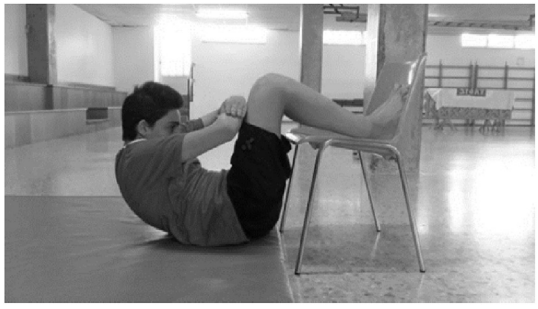


**Fig. 2.** Bench trunk curl test final position.

### 2.5. Biering-Sörensentest (SOR)

The Biering-Sörensen test (SOR) measures the endurance of the trunk extensor musculature. SOR is the test most commonly used in this assessment. Its validity and reliability has been shown in adolescents and adults (Champagne and Descarreaux, 2008). The test was carried out by positioning participants in a prone position on a table, with their anterior superior iliac spines aligned with the edge of the table. Lower limbs were held against the table by an assistant. Arms were crossed behind the back. From this position, the subjects were asked to keep their trunk in a horizontal position. The end of the SOR test was determined by one or both criteria: a) the participants reported maximum fatigue in their extensor muscles, and/or b) the students lost the horizontal position (see Figs. 3 and 4). Test duration was recorded in seconds (Biering-Sorensen, 1984).

### 2.6. Toe touch test (TT)

The toe touch test (TT) was conducted to evaluate hamstring extensibility. Its validity and reliability has been demonstrated in school children (Ayala et al., 2012). The participants were placed in the standing position on the measuring box, with their knees extended and their feet spread to the width of their hips. From this position, the subjects were asked to bend forward as far as possible, sliding their hands along the box rule to reach the maximal distance (see Fig. 5). The point at which participant's fingertips were in line with their toes was marked as Zero centimeters, and the measurements were negative if they did not reach the line of their toes, and positive if they did so.

### 2.7. Statistical analysis

The hypothesis of normality was analyzed via the Kolmogorov-Smirnov test. Descriptive statistics for quantitative variables (means, standard deviations and range) and qualitative (frequency) were calculated. A two-way analysis of variance (ANOVA), was used for group (GE and GC) and type of measurement (pre-, post- and re-test), and a least significant difference post hoc comparison (Bonferroni) was used to identify the mean differences between the groups and the measures. An unpaired *t*-test was used to assess the differences in anthropometric variables and age between groups. All data analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., version 21.0, Chicago, IL, USA) for Windows. Statistical significance was set at $p \leq 0.05$.

## 3. Results

The characteristics of the participants in total and by group are presented in Table 2. No significant differences were found in age, body mass, height or BMI between the EG and the CG. CG group was formed by a 50.81% of female (n = 94) and 49.19% of male (n = 91); and experimental group was formed by 44.92% (n = 115) of female and 55.08% of male (n = 141).

**Fig. 3.** Biering-Sörensen test set position.

**Fig. 4.** Biering-Sörensen test final position.

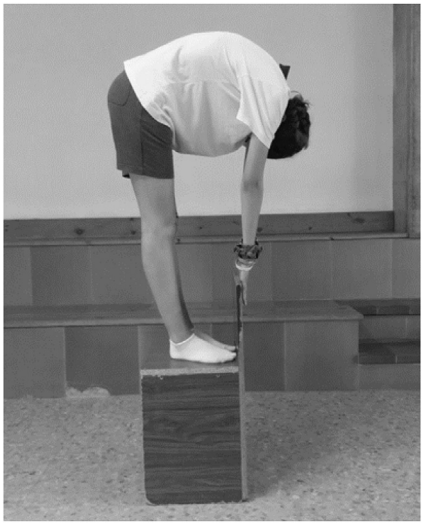


**Fig. 5.** Toe touch test.

The results in the pre-, post- and re-tests of all the variables analyzed, the changes between the pre- and the post-test (Dif. Post-Pre), and the post- and the re-test (Dif. Re-Post), including 95% confidence intervals (CI95%) and p values (significance) are presented in Table 3. EG and CG did not differ in pre-test in the test. EG improve significantly in BTC, Sorensen and TT test after the program in 9.37 ± 22.8 repetition, 19.4 ± 55.3 s and 2.75 ± 4.7 cm, respectively; and CG did no show change between pre- and post-test. EG show higher result at BTC and SOR test than CG after the program, and higher result at BTC test after the detraining period, significantly. After the detraining period, EG showed a significative decrease at SOR test of 21.19 ± 56.4 s; maintained the improvement in the rest of the test without significantly difference.

## 4. Discussion

The objective of this research was to assess the effect of an exercise adapted program from PM of 12 weeks duration, with a frequency of 2 sessions of 10 min per week within Physical Education classes, on the endurance of the trunk musculature and hamstring flexibility in adolescents; and to evaluate the retention of the changes produced after application of the program. The results showed that the intervention as described above produces significant improvements in the endurance of the trunk musculature, and maintains the improvement for the flexor muscles for

**Table 2**
General characteristics of the two groups.

| | | TOTAL (n = 441) | GROUP | |
|---|---|---|---|---|
| | | | EG (n = 256) | CG (n = 185) |
| Gender | Male | 52.61% (232) | 55.08% (n = 141) | 49.19% (n = 91) |
| | Female | 47.39% (209) | 44.92% (n = 115) | 50.81% (n = 94) |
| Age | | 13.90 ± 1.3 | 13.78 ± 1.3 | 14.06 ± 1.1 |
| Height (cm) | | 164.54 ± 8.8 | 163.54 ± 9.3 | 165.93 ± 8.0 |
| Weight (kg) | | 60.75 ± 14.0 | 59.74 ± 14.3 | 62.13 ± 13.4 |
| BMI (kg/m2) | | 22.30 ± 4.2 | 22.16 ± 4.2 | 22.49 ± 4.2 |

Legend: EG = experimental group; CG = control group; BMI = body mass index.

**Table 3**
Pre-post-retest results, pre-post-re-test changes, mean, SD (standard deviation), confidence interval (95% CI) and p value (significance) distributed in EG and CG.

| | Mean ± SD | | | PRE- POST-TEST CHANGES | | | POST- RE-TEST CHANGES | | |
|---|---|---|---|---|---|---|---|---|---|
| | PRE- | POST- | RE- | Dif. Post-Pre (Mean ± SD) | CI 95% (Mpre-Mpost-) | p valor | Dif. Re-Post (Mean ± SD) | CI 95% (Mpre-Mpost-) | p valor |
| BTC | | | | | | | | | |
| CG (n = 185) | 53.17 ± 21.4 | 51.65 ± 18.9[b] | 50.32 ± 18.5[b] | −1.51 ± 19.6[b] | −1.98; 5.00 | .889 | −1.34 ± 13.8 | −1.12; 3.78 | .570 |
| EG (n = 256) | 52.88 ± 24.5 | 62.29 ± 24.8[b] | 61.29 ± 26.5[b] | 9.37 ± 22.8[b] | 5.91; 12.81 | .000[a] | −0.89 ± 4.1 | −3.95; 2.16 | .861 |
| SOR | | | | | | | | | |
| CG (n = 185) | 116.94 ± 66.9 | 113.25 ± 67.2[b] | 121.49 ± 57.8 | −3.86 ± 52.5[b] | −13.03; 5.65 | .714 | 8.24 ± 48.6[b] | 0.39; 16.86 | .067[a] |
| EG (n = 256) | 126.98 ± 72.7 | 146.37 ± 68.5[b] | 125.04 ± 69.0 | 19.4 ± 55.3[b] | 27.73; 11.04 | .000[a] | −21.19 ± 56.4[b] | −29.70; - 12.77 | .000[a] |
| TT | | | | | | | | | |
| CG (n = 185) | −5.27 ± 6.9 | −5.41 ± 7.6 | −5.27 ± 7.6 | −0.14 ± 4.5[b] | −0.94–0.65 | .964 | 0.14 ± 3.3 | −0.45; −0.74 | .917 |
| EG (n = 256) | −6.79 ± 8.1 | −4.04 ± 9.5 | −3.80 ± 9.5 | 2.75 ± 4.7[b] | 1.98; 3.38 | .000[a] | 0.25 ± 4.1 | −0.36; 0.86 | .705 |

Legend: BTC= Bench trunk curl; SOR= Sörensen; TT = Toe-touch; SD = standard deviation;[a] = difference p<0,05 intragroup; [b] = difference p<0.05 intergroup.

more than three months. Another study analyzed the effect of an exercise adapted program from PM on the endurance of the trunk musculature at a frequency of 2 weekly sessions for 6 weeks with a duration of 55 min per session (González-Gálvez et al., 2014). As in the present research, an increase in trunk endurance was found for both the flexor and extensor muscles (González-Gálvez et al., 2014), although González-González et al. (2014) found greater improvement (BTC: MS = 20.76 rep., FS = 13.54 rep./SOR: MS = 55.71 s, FS = 32.2 s/Our study: BTC = 9.37 rep; SOR = 19.4 s). It must be noted that González-Gálvez et al. (2014) worked on the endurance of the trunk for 35 min per session, whereas the present investigation used 7.5 min, although the investigation lasted twice as many weeks. It therefore seems that training volume could be important in improving this variable after the duration of the program, however, future research is recommended to corroborate this. In addition, there is no any research that applied original PM in adolescent with a similar objective of this study. This is an area for further investigation.

The use of a specific program for schoolchildren, whether for six weeks with one session per week in the initial part of the session (Allen et al., 2014); for ten weeks with two weekly sessions, in the first part of the class (Durall et al., 2009); for 12 weeks with three sessions of 60 min per week (Kumar et al., 2015); or combining endurance work for the trunk musculature with hamstring stretching for six weeks, for two full sessions per week (Moreira et al., 2012), increases the endurance of the trunk flexor and extensor musculature, regardless of the test used for its assessment and the nature of the effort made (isometric or concentric work). Other studies also found no changes in the control group (Durall et al., 2009; Kumar et al., 2015; Moreira et al., 2012), coinciding with the present research.

The present research shows a maintenance of the gains obtained in endurance for the trunk flexor musculature, and that the endurance of the extensor muscles returned to its initial state 12 weeks after training. Although there are only a few studies of the effect of detraining on the endurance of the trunk in schoolchildren, our results support their findings. Faigenbaum et al. (2013) and Mayorga-Vega et al. (2013) did not report significant losses in the endurance of the flexor trunk musculature after an eight-week detraining period using an isokinetic test. No research has been found to analyze the effect of detraining on the endurance of the trunk extensor musculature in schoolchildren, and there is just one that assess the effect of detraining after a specific trunk strength or resistance training program in adult (Tucci et al., 1991). These authors, after a 10 or 12 weeks of lumbar extension strength program, also reported a decrease in lumbar isometric endurance after a four week of detraining period.

Other researchers assessed the effect of the detraining on resistance muscle after other types of exercise programs that do not include a specific trunk muscle strength. Muehlbauer et al. (2012) used a sample of young adults after 12 weeks of indoor climbing training. They concluded that after eight weeks of detraining there was a significant reduction in the isometric endurance of the flexor and extensor muscles of the trunk. Tsolakis et al. (2004) applied two month of resistance training program and assess the effect of detraining of the two month in adolescent. They showed a significant reduction of general isometric endurance, but not isokinetic endurance. The same dynamic has been demonstrated in adults in relation to the effect of detraining on the type of endurance (Ishida et al., 1990; Mujika and Padilla, 2000). On the other hand, many authors also highlight the importance of exercise intensityover duration and frequency on the effect of detraining (Behringer et al., 2010; Fatouros et al., 2005), and that could be applicable to our results. These studies apply and assess different programs and exercise programs than the present study, therefore the comparison must be made with caution. More research is necessary in this regard.

The Bench turn curl test has been used in previous investigations with school populations (González-Gálvez et al., 2014; Moya-Ramón et al., 2017). It is found that two of the studies used static tests (Durall et al., 2009, Moreira et al., 2012) and the other two, dynamic tests (Allen et al., 2014; Kumar et al., 2015). A dynamic test was used in the present study because they report greater reliability than isometric tests (Moreland et al., 1997). Some

studies used specific test in which the subjects had to maintain a 90° isometric flexed hip (Durall et al., 2009). In this test, the abdominal musculature is not specifically evaluated requiring important hip flexor muscle involvement (Augustsson et al., 2009; Chong et al., 2006) generating a lumbar compression values between 3230 and 3500 N, surpassing the healthy recommendation of 3000 N (Axler and McGill, 1997; McGill, 1995).

The Biering-Sorensen test has been used in a large number of previous investigations (Durall et al., 2009; González-Gálvez et al., 2014; Moreira et al., 2012). Kumar et al. (2015) used the back leg chest dynamometer test. This test measures the extensor strength of the trunk (Hannibal et al., 2006). It has been reported that endurance-strength (McGill, 2001). Allen et al. (2014) uses the parallel roman chair dynamic trunk extension test. The contribution of hip extensor musculature in this dynamic test limits their validity by not specifically isolating the trunk extensor musculature (Clark et al. 2002, 2003).

Another important finding of the present investigation was that an improvement in hamstring extensibility was found after 12 weeks of training with the exercise adapted from PM. Two previous studies have analyzed the effects of the application of a program with the exercise adapted from PM on hamstring extensibility in adolescents (González-Gálvez et al., 2014, 2015). Both investigations applied an adapted Pilates program for six weeks, with two weekly sessions and a duration of 55 min per session. Coinciding with the results of the present research, improvements in hamstring extensibility were found after the intervention program. The improvements found in flexibility in this study (2.75 cm) are slightly lower than those reported by González-Gálvez et al. (2014, 2015), which found improvements in the MS of 3.38 cm, and the FS of 3.54 and 3.85 cm. This could be due to the fact that the volume of stretches used in González-Gálvez et al. (2014, 2015) was greater, since they stretched for 10 min per session compared to 2.5 min in the present investigation, although the current program lasted twice as long. Santonja et al. (2007) and Rodríguez-García et al. (2008) reported that the volume of stretching could be the key element in analyzing the gains from different programs in schoolchildren.

A large number of studies have analyzed the effect of stretching in a systematic way to improve the flexibility of the musculoskeletal muscle. All show significant improvements from two weekly sessions for 5 to 31 weeks, from 3 to 7 min per session (Bohajar-Lax et al., 2015; Mayorga-Vega et al., 2014a, 2014b; Moreira et al., 2012; Rodríguez et al., 2008; Sainz de Baranda, 2009; Sainz de Baranda et al., 2006; Sánchez-Rivas et al., 2014). The present investigation supports previous findings, by showing that 2.5 min of stretching, in two weekly sessions for 12 weeks, is sufficient to improve extensibility, compared to no changes in the group control.

The present study found that the gains obtained in hamstring extensibility were retained three months after the end of the program. Two previous investigations have assessed the retention of the flexibility gain five weeks after applying a stretching program (Mayorga-Vega et al., 2014a, 2014b). The stretching program consisted in three 20-s set of five hamstring stretching exercise, twice session per week, during 8 weeks. The results showed a significant loss of flexibility with respect to the post-test, however significant differences were also found with respect to the pre-test, which indicated that after five weeks some of the improvements were lost, but that there was still greater extensibility than before the program began (Mayorga-Vega et al., 2014a, 2014b). The differences between the findings of these studies and those of the present investigation could be due to the difference in ages of the samples studied, the duration or the characteristics of the exercise program carried out. Further investigation is necessary in this area. The used of TT test is recommended because the bending movements of the standing trunk are very common movements, especially in the activities of daily life, and in many sports activities (Sainz de Baranda et al., 2006).

### 4.1. Limitations

Although the participants were randomized into an experimental group and control group, there were differences in groups size because some participants from the control group were missed for the post-test. However, the representation of the gender was equal for both groups. On the other hand, the lack of the study about the effect of the detraining after a trunk endurance program in adolescents, limits the capacity of the discussion of our result.

## 5. Conclusion

A 12-week exercise adapted program from PM, with a frequency of two sessions of 10 min per week, produces improvements in the strength-endurance of the trunk muscle and in hamstring flexibility, maintaining these gains three months after the end of the program. The exercises adapted from PM, therefore, seem to be an effective method for use in Physical Education classes for the improvement of a healthy physical condition in a global way.

### 5.1. Clinical relevance

The present study highlights and presents evidence of the effect of exercises adapted from PM on trunk endurance muscle and hamstring extensibility in adolescents that indicate to be a good exercise for the health of the spine.

In addition, after 12 weeks of detraining there is no decrease of the improvement in trunk flexor endurance muscle and hamstring endurance, although there is a decrease in the trunk extensor endurance. This suggests that it may not be necessary to apply this program all school year in order to contribute to the health of the spine in regards to trunk flexor endurance muscle or hamstring extensibility, and that it is necessarily a better adaptation of the program to influence trunk extensor muscle endurance and avoid the effect of detraining.

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## Declaration of competing interest

Nothing to declare.

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