

Acute effect of a static- and dynamic-based stretching warm-up on standing long jump performance in primary schoolchildren

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ABSTRACT: The aim of the present study was to compare the acute effect of a static- vs dynamic-based stretching warm-up on standing long jump (SLJ) performance in primary schoolchildren. The sample was composed of 76 schoolchildren, 43 girls and 33 boys, aged 9–10 years old from three fourth-grade classes of Primary Education. The three groups were cluster-randomly assigned to the control (CG), static (SG) or dynamic (DG) groups. All the schoolchildren performed a standardized warm-up consisting of mobility exercises (five minutes), jogging (five minutes) and the SLJ test. Afterwards the CG schoolchildren received jump theory (eight minutes), the SG performed static stretching (eight minutes) and the DG performed dynamic-bounces stretching (eight minutes). Afterwards, all of them performed the SLJ test again. The results of the one-way ANOVA ($F_{2,73} = 34.184$; $p < 0.001$; $\eta^2_p = 0.484$), followed by the pairwise comparisons with the Bonferroni adjustment, showed that the DG students ($M_{\Delta} = 11.07$, $SE = 1.42$) made a significant statistical improvement in their SJL levels compared with the CG ($M_{\Delta} = -3.00$, $SE = 1.89$; $p < 0.001$, $d = 1.51$) and SG students ($M_{\Delta} = -1.85$, $SE = 0.67$; $p < 0.001$, $d = 1.38$). However, statistically significant differences between the CG and SG students were not found ($p > 0.05$, $d = 0.12$). The dynamic-bouncing stretch as a final part of a warm-up improves explosive strength performance in primary schoolchildren, and seems to be a good option before carrying out explosive strength activities of the lower body.

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INTRODUCTION

Warm-up is one of the most common practices at the beginning of Physical Education (PE) classes in schools, training sessions or competitions for children [1]. It is important for all students to warm-up before participating in the main activities of a PE class [2]. In order to prevent injuries and optimize performance [3]. Warm-ups are generally composed of low-to-moderate intensity aerobic activity, stretching of the main muscle groups and specific exercises of the sport to be performed [4].

Muscular fitness is an important marker of health in children [5]. Lower-body explosive strength is one of the dimensions of muscular fitness commonly included in fitness test batteries for youth [6]. The standing long jump (SLJ) test is a reliable and valid measurement of the lower body explosive strength in schoolchildren [7]. Additionally, the SLJ test predicts lower body muscular strength better than other common field tests such as the vertical jump test in children 7–12 years old [8]. Due to its practical, time-efficient, low cost and equipment requirements, the SLJ test was proposed as a general index of muscular fitness in youth 6–12 years old [9].

Previous studies have found that prolonged static stretching, while improving range of motion, has no effect on counter-movement jumps

in girl gymnasts [10]. Moreover, static stretching has no negative effect on the vertical jump of adolescent tennis players [11], and when comparing the effect of static and dynamic stretching on vertical jumps of female college volleyball players, no differences were found [12]. In contrast, other studies that compared a warm-up with dynamic exercises to a warm-up with static stretching found that static stretching impaired explosive strength performance. In a sample of adolescent athletes, dynamic exercises improved vertical jumps while static stretching produced a clear decrease [13]. In elite youth soccer players dynamic exercises produced a superior sprint and vertical jump compared to a warm-up with static stretching [14]. In college athletes, the horizontal jump and the vertical jump showed significantly greater improvement after the dynamic exercises compared to the results after the warm-up with static stretching [15]. Moreover, in young female handball players, dynamic stretching improved sprint performance to a greater extent than static stretching and no stretching as a final part of a warm-up [16]. In addition, when comparing dynamic with static stretch modalities as part of a warm-up, the former (dynamic stretching) is associated with an increase in heart rate, core temperature, greater nervous system

stimulation, and an increase in peak torque [17]. In this sense, as doubts about the value of static stretching grow, dynamic exercise offers a more beneficial warm-up procedure [2].

Thus, there is currently a debate on whether stretching should be included in the warm-up prior to doing sport and how a stretching should be designed and executed [18]. Some authors compared warm-up protocols in children and found that warming up with static stretching decreased vertical and long jumps compared to performing dynamic exercises and jumps in the warm-up [19]. Similarly, other controlled studies in children found that the warm-up with static stretching decreased vertical jumps, while the one containing dynamic exercises increased vertical jump performance [20, 21]. To our knowledge, there are no previous studies comparing the static-passive versus dynamic-bouncing stretching (soft bounces) within a warm-up, in the SLJ performance of school-age children. Consequently, the purpose of the present study was to examine the acute effect of static and dynamic stretching (soft bounces) as a final part of a warm-up on the performance of the SLJ test among primary schoolchildren in a PE setting.

MATERIALS AND METHODS

Participants

The study protocol was first approved by the Ethical Committee of the University of Malaga. After the school approvals were obtained, schoolchildren and their legal guardians were fully informed about all the features of the study and were required to sign an informed consent document. The study protocol respected the current agreement of the Declaration of Helsinki on ethical principles for research involving human subjects.

A sample of 76 schoolchildren, 33 boys and 43 girls, aged 9–10 years old from three different fourth-grade PE classes at a public primary school center, located in an urban area of the city of Malaga, participated in the present study. For practical reasons and the nature of the present study (i.e., intervention focused on natural groups in a school setting) a cluster randomized controlled trial design was used [22]. The three natural classes were assigned randomly to form one of the following study groups: static group (SG; $n = 27$), dynamic group (DG; $n = 27$) or the control group (CG; $n = 22$).

The following inclusion criteria were considered: (a) being enrolled in the fourth grade (grade in which permission to do the study was obtained); (b) being free of orthopedic disorders such as episodes of hamstring and/or lumbar injuries, fractures, surgery or pain in the spine or hamstring and/or lumbar muscles over the past six months [23]; (c) presenting the corresponding verbal informed assent by the schoolchildren themselves; and (d) presenting the corresponding signed written informed consent by their legal guardians. The exclusion criteria were: (a) not attending to both the familiarization and intervention session, and (b) not correctly performing the SLJ test. Finally, all of the 76 invited schoolchildren that agreed to participate, met satisfactorily the inclusion and exclusion criteria. A priori sample size calculation was estimated with the F-test ANOVA

function by the G*Power Version 3.1.9.4 for Windows. Parameters were established as follows: effect size $f = 0.40$, significance level $\alpha = 0.05$, statistical power $(1 - \beta) = 0.80$, and number of groups $n = 3$. A minimum final sample size of 66 (i.e., 22 per group) was estimated. For general characteristics of the included participants, see the Results section.

Measurements

All the measures were performed during the regularly scheduled PE classes. Prior to the intervention, information about participants' gender, age and extra-curricular sport participation was collected. Then, anthropometric measures were also taken during the same class. A week before of the SLJ measurement, all the participants carried out a familiarization session. During the familiarization session, the execution of the SLJ was explained in detail and students were able to practice it several times. Then, students carried out the SLJ test before (pre-intervention) and after (post-intervention) the warm-up. A description of the protocol of each measurement is described below.

Extra-curricular sport. Students' extra-curricular sport participation was collected through a short survey. Participants were asked if they were enrolled in any organized sport during their free time, which kind of sport(s), if they were federated, and how many days and average time per session they used to participate. Afterwards, based on previous studies [24, 22], data were dichotomized as schoolchildren that either regularly participated or did not in extra-curricular sport at least twice per week with an average session time equal or higher than 60 minutes.

Anthropometric. Participants' body mass and height were measured and then the body mass index (BMI) was calculated as body mass/height squared (kg/m^2). During the measurement of body mass and height participants were in shorts, T-shirts and barefoot. For the body mass measure, once the scale read zero, the participant stood in the centre of the scale without support and with their weight distributed evenly on both feet. For the body height measurement, the student stood with their feet and heels together, buttocks and upper part of their back touching the scale, and with their head placed in the Frankfort plane. The average of two measurements for both body mass and height was retained [25].

Standing long jump test. Students' lower body explosive muscular strength was measured with the standardized protocol of the SLJ test. A detailed description of the procedure has already been published [9]. In short, the participants stood behind the starting line with their feet together and jumped forward as far as they could. The distance was measured from the start line to the point closest to the landing line (the back of the heel). The test was repeated twice, and the best score was recorded (in cm). The SLJ test was carried out by the same tester, instrument, and under similar environmental

conditions (temperature between 20–22°C). Additionally, intervention took place in an indoor, non-slippery sports facility.

Procedures

All the students performed a standardized warm-up consisting of dynamic exercises (rotation of ankles, flexion-extension of knees, flexion-extension of hips, flexion-extension of shoulders, wrist rotations in both directions, and right and left neck rotations), and five minutes of jogging at low intensity. The students were standing and performing the dynamic exercises according to the teacher's instructions (45 seconds were performed with each joint and five seconds of rest between each exercise). Then, students performed the SLJ test (i.e., pre-intervention). Afterwards, the CG students received eight minutes of theoretical explanations about the jump (sitting on the floor with legs crossed), the SG students performed eight minutes of static-passive stretches, and the DG students performed eight minutes of dynamic stretches (soft bounces). Finally, all of them performed the SLJ test again (i.e., post-intervention). The warming up and the SLJ evaluation were carried out by the same PE teacher at the participating center for all the groups (Figure 1).

Stretching exercises. The participants in the SG and DG performed calf and quadriceps stretches for eight minutes (four minutes of work and four minutes of rest). Two unipodal exercises were performed (one repetition for the right calf and one repetition for the left calf, then one repetition for the right quadriceps and one repetition for the left quadriceps), one 60 second stretch per muscle in a single repetition with 60 seconds of rest between each exercise. The stretched position was held gently until the end point of the range of motion was reached (i.e., stretched to the point of feeling tightness, but no pain). Once this position was achieved, the participants held it for 60 seconds in the SG and the participants in the DG started to bounce softly for 60 seconds (Figure 2).

Statistical analysis

Descriptive statistics (mean \pm standard deviation/error or percentage) for general characteristics of the participants and dependent variables were calculated. Statistical test assumptions were checked by common procedures (e.g., histograms and normal Q-Q plots for normality). Chi-squared analyses were carried out to test the ratio differences of gender and extra-curricular sport practitioners be-

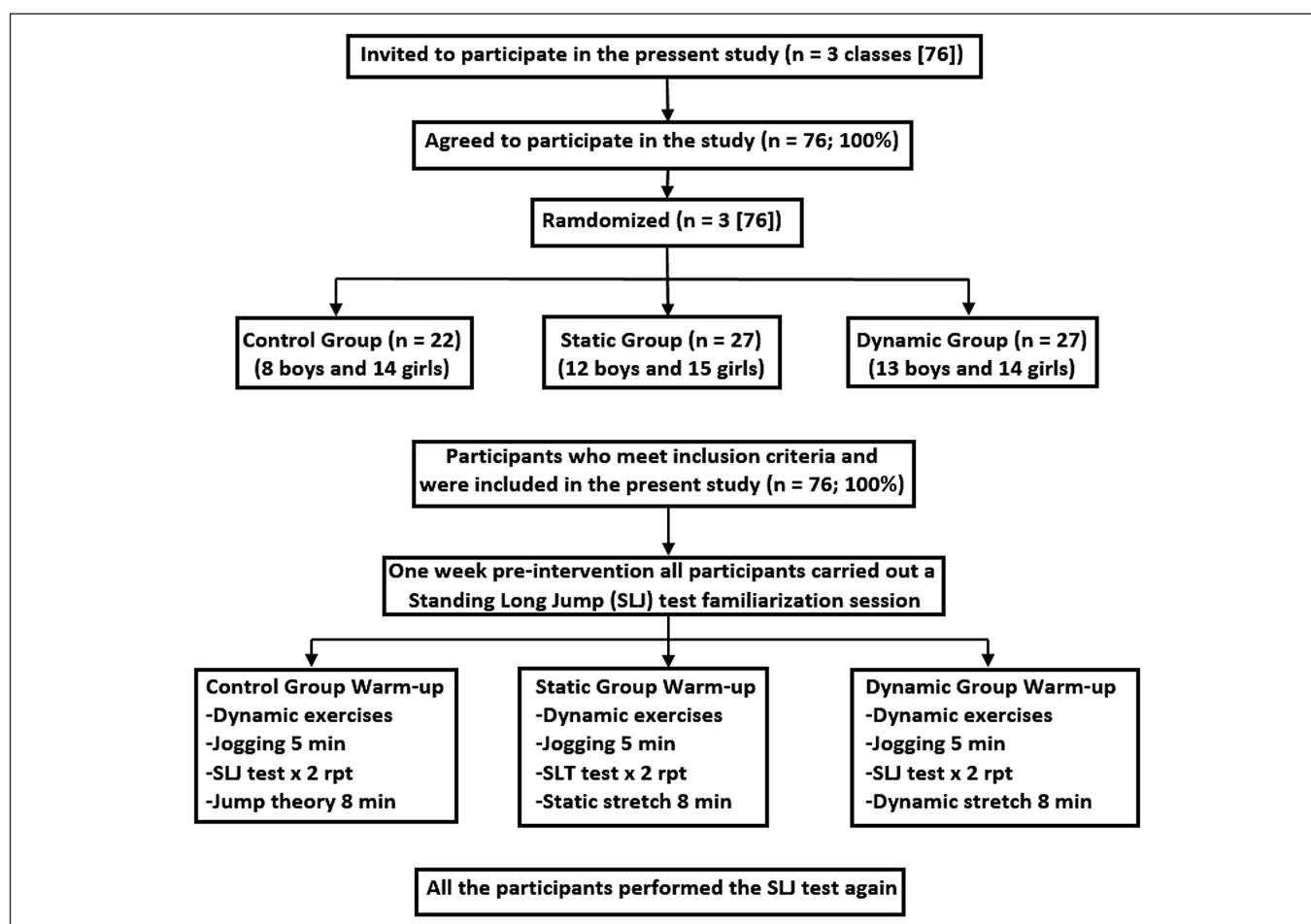


FIG. 1. Flow chart corresponding to the participants and to the procedure of the present study.

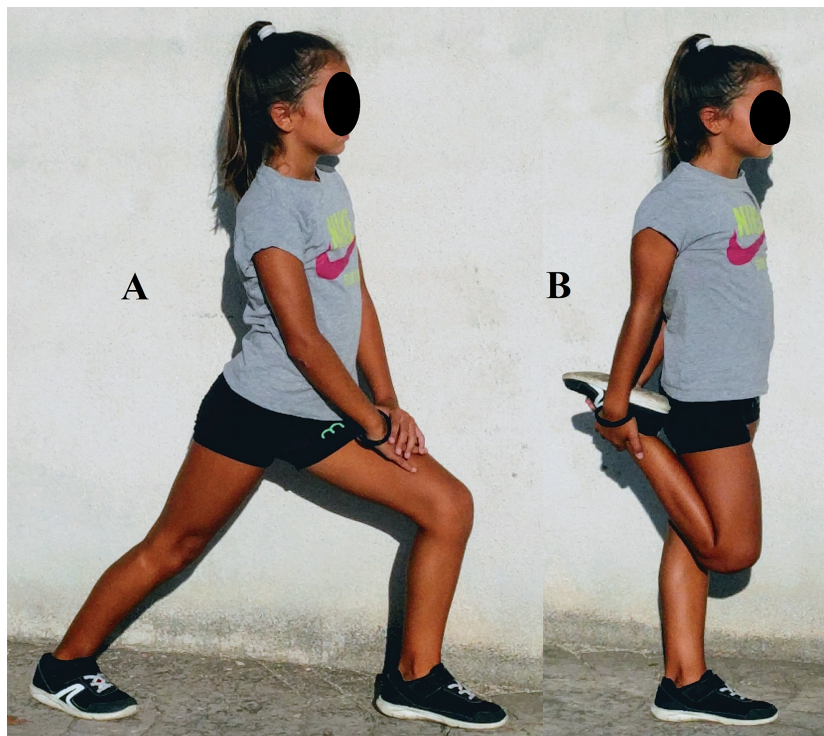


FIG. 2. Stretching exercises performed at the end of the warm-up period during the intervention session: (a) calf, and (b) quadriceps.

tween the three groups. A one-way analysis of variance (ANOVA) was conducted to examine potential differences between the three groups in terms of body mass, body height, body mass index, and SLJ baseline levels. Then, the acute effect of the static- and dynamic-based stretching warm-ups on SLJ test performance was examined using a one-way ANOVA, including *group* as an independent variable (CG, SG and DG) and *SLJ* change scores (i.e., post-intervention – pre-intervention scores) as a dependent variable. Subsequently, for the *post hoc* pairwise comparisons, the Bonferroni adjustment was used. From all the potential confounding variables explored (i.e., gender, body mass, body height, body mass index, and extra-curricular sport), any covariable was used. Effect sizes were estimated using the partial eta squared (η^2_p) and Cohen's *d* for the overall and pairwise comparisons, respectively. All statistical analyses were performed using the SPSS Version 21.0 for Windows (IBM® SPSS® Statistics). The statistical significance level was set at $p < 0.05$.

RESULTS

General characteristics. Table 1 shows the general characteristics of the participants and differences between the three groups. The chi-square analysis showed that the three groups had a balanced representation of gender and extra-curricular sports practitioners ($p > 0.05$). Additionally, the one-way ANOVA results did not show statistically significant differences in terms of body height and SLJ baseline scores between the three groups ($p > 0.05$). However, the

one-way ANOVA results, followed by the *post hoc* pairwise comparisons with the Bonferroni adjustment, showed that the CG students had statistically significant higher values of body mass and body mass index than the SG and DG ($p < 0.001$).

Standing long jump performance. Figure 3 shows the acute effect of a static- and dynamic-based stretching warm-up on SLJ perfor-

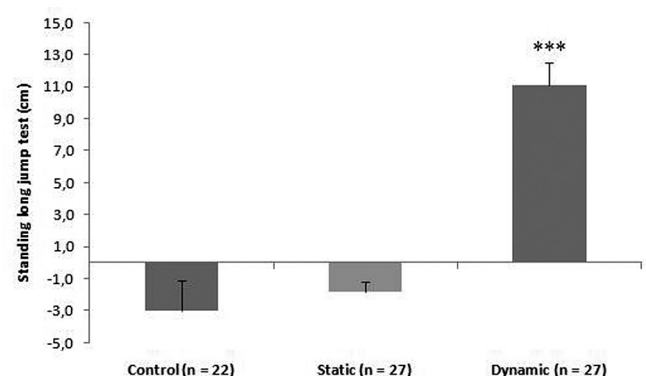


FIG. 3. Acute effect of the static- and dynamic-based stretching warm-ups on SLJ performance in primary schoolchildren. Values are reported as mean (bars) and standard error (bar of error). Results of the one-way ANOVA ($p < 0.001$) followed by the *post hoc* pairwise comparisons with the Bonferroni adjustment: Dynamic vs. control/ static groups (***) $p < 0.001$.

TABLE 1. General characteristics of the participants and differences between the three groups

	Total (n = 76)	Control (n = 22)	Static (n = 27)	Dinamic (n = 27)	p ^a
Gender (girls/ boys)	52.6/ 47.4	63.6/ 36.4	44.4/ 55.6	51.9/ 48.1	0.406
Body mass (kg)	34.0 (2.9)	36.8 (2.3)*	32.3 (2.2)	33.5 (2.3)	< 0.001
Body height (cm)	134.7 (3.0)	133.8 (2.2)	134.9 (2.9)	135.3 (3.5)	0.208
Body mass index (kg/ m ²)	18.8 (1.7)	20.6 (1.2)*	17.8 (1.4)	18.3 (1.3)	< 0.001
Extra-curricular sport (no/ yes)	81.6/ 18.4	77.3/ 22.7	85.2/ 14.8	81.5/ 18.5	0.777
Standing long jump (cm) ^b	103.0 (19.3)	104.2 (17.0)	102.1 (20.9)	103.0 (20.1)	0.932

Note. Data are reported as mean (standard deviation) or percentage.

^a Significance level from the one-way analysis of variance for body mass, body height, body mass index and SLJ baseline scores, and from the chi squared test for the gender and extra-curricular sport ratios. *Post hoc* pairwise comparisons with the Bonferroni adjustment: Difference statistically significant between the control and static/dinamic groups (*p < 0.001).

^b SLJ baseline scores.

mance in primary schoolchildren. The results of the one-way ANOVA showed overall statistically significant differences on the SLJ change scores (i.e., post-intervention – pre-intervention scores) between the three groups ($F_{2,73} = 34.184$; $p < 0.001$; $\eta^2_p = 0.484$). Subsequently, *post hoc* pairwise comparisons with the Bonferroni adjustment showed that the DG students ($M_{\Delta} = 11.07$, $SE = 1.42$) significantly improved statistically their SLJ levels compared with the CG ($M_{\Delta} = -3.00$, $SE = 1.89$; $p < 0.001$, $d = 1.51$) and SG students ($M_{\Delta} = -1.85$, $SE = 0.67$; $p < 0.001$, $d = 1.38$). However, statistically significant differences between the CG and SG students were not found ($p > 0.05$, $d = 0.12$).

DISCUSSION

The purpose of the present study was to examine the acute effect of static and dynamic stretching (soft bounces) as a final part of a warm-up on the performance of the SLJ test among primary schoolchildren in a PE setting. The results of the present study show that dynamic stretching (soft bounces) as a final part of a warm-up increases the performance on the SLJ test compared to static-passive stretching and control in fourth grade Primary Education schoolchildren.

They compared the effect of three warm-up protocols on vertical and long jumps in 60 children 11-year-old average, and found that warming up with static stretching decreases children’s performance compared to performing dynamic exercises and jumps in the warm-up [19]. Similarly, other controlled studies in children found that the warm-up ending with static stretching decreased vertical jumps, while the one containing dynamic exercises increased vertical jump performance [20, 21]. These findings suggest that warm-up protocols that include only static stretching may have unintended adverse consequences on anaerobic performance in children [2]. On the other hand, dynamic exercises can reverse the negative effect caused by performing static stretches [26].

All these studies compared the effect of static stretching with dynamic exercises, not with dynamic stretching. Although some authors suggest that these dynamic exercises could be taken as dynamic stretches since the muscles are stretched to a new range of motion and then forced to contract to perform the desired action [2]. But in any case, it could be said that dynamic exercises are dynamic stretches using a bouncing technique.

Some authors stated, it is important to understand that a dynamic stretch does not involve a bouncing-type movement, which is characteristic of a ballistic stretch, but rather a controlled elongation of a specific muscle group [2]. We completely disagree with the opinion of these authors. A bouncing-type movement is simply one of the possibilities within a range of dynamic stretching techniques [27].

On the other hand, among young people the practice of dynamic techniques has been rejected because of a greater potential risk of muscle injury [28]. Nevertheless, as several authors suggest [27, 29], dynamic stretching exercises may not be harmful when practiced gently.

Perhaps the greatest jumping performance achieved due to dynamic stretching when compared with static stretch as part of a warm up is due to an increase in heart rate, core temperature, greater nervous system stimulation, and an increase in peak torque associated with the dynamic stretch [17]. An 8-minute warm-up improves sprint performance and decreases the perception of fatigue when compared to 15 and 25 minute durations [30]. In the present study, the duration of the exercising in the warm-up was 18 minutes for the 2 groups doing stretching and 10 minutes for the group not stretching (because for 8 minutes the students were receiving theoretical information). However, the 18-minute warm-up with dynamic stretching performed best compared to the other two groups. It would be interesting to compare different warm-up durations with the same stretching technique.

To our knowledge, this is the first study that compares the effect of static-passive versus dynamic stretching (soft bounce) within a warm-up, in the SLJ performance of school-age children. The novelty of this article is that there is not a single study that compares a warm-up with static stretching and another with dynamic (bounces) stretching in any type of sample on any type of expression of strength. The use of a research design that compares three groups also adds quality to this study. It allows us to control that results are due to the stretching technique and not to other possible external factors.

However, some limitations should also be considered. First of all, due to human and time restrictions, a larger sample could not be examined. This fact could limit the generalizability of the obtained outcomes to the particular setting studied.

A more conclusive study could be a crossover study so that each warm-up condition (without stretching/static/dynamic respectively) could be compared, in one big sample. However, for practical reasons and the nature of the present study (i.e., intervention focused on natural groups in a school setting) a cluster crossover design would be the only feasible option. However, since there were 3 study conditions (i.e., Static, Dynamic, and Control), which represents an important novel in this study (i.e., comparing the static and dynamic stretching in the same study), 9 groups (classes) were required and there was no access to that number (only 3). Therefore, in the present study, a randomized control trial cluster design was chosen instead.

Future research interventions should compare the effectiveness of different stretching techniques within warm-up protocols on

performance improvements among schoolchildren. That way, we could know the most appropriate technique to be used in a PE setting.

Practical applications. To include stretching using the bounce technique as a final part of the warm-up seems to be a good option before carrying out explosive strength activities of the lower body. In addition, apart from being an effective way to improve flexibility, the dynamic (bouncing) technique seems to be completely safe among students in a PE setting. This knowledge could help and guide teachers to design warm-ups protocols that ensure a feasible and effective expression of lower body explosive muscular strength in the PE setting.

CONCLUSIONS

The dynamic stretch (soft bounces) compared with the static stretch and no stretch at all, as a final part of a warm-up, improves performance on the SLJ in primary schoolchildren. Carrying out static stretching at the end of the warm-up is the same as not doing in terms of SLJ performance. The dynamic (bouncing) technique did not cause any discomfort or injury to the schoolchildren during the study.

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Conflict of interest declaration

The authors declare no conflict of interest.

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