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Does the type of flexibility used before a Physical Education class have an influence?

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Abstract

The use of muscle stretching techniques has long been practised prior to physical activities to increase activation, increase joint amplitude or as part of warm-up techniques. In recent years, there has been discrepancy in the use of static stretching (STA), dynamic or intermittent stretching (DYN), or no stretching (CON) before starting the Physical Education session. The aim of this study was to find out which type of flexibility work would obtain better results in the countermovement jump (CMJ) with the variables: relative strength index (RSI), jump height (HGT) and contact time (CT) with a contact platform. 86 participants aged 16.74 ± 0.19 years, 65.17 ± 30.03 kg and 1.71 ± 0.09 m took part in this research. All participants were randomised to the 3 protocols, 2 stretching protocols (STA and DYN) for 30 seconds and 1 control without any stretching (CON). The results showed significant increases in the RSI and HGT ($p < .001$) in the DYN condition vs. CON and STA. On the other hand, CT showed significant increases in STA with respect to CON ($p < .01$) and DYN. From the results obtained, it could be affirmed that an acute programme of dynamic stretching could produce improvements on countermovement jumping (CMJ) compared to no stretching or a 30 s maintenance of muscle elongation.

Keywords: CMJ, dynamic flexibility, Physical Education, RSI.

Introduction

Flexibility is considered one of the four physical-motor skills along with speed, strength and endurance (Castañer & Camerino, 2022; Monguillot Hernando et al., 2015). This concept is understood as the property of a body to deform under an applied force and return to its initial state once removed (Porta, 1987). Multiple methodologies for their conditioning, maintenance, and improvement have been available for years (Castañer & Camerino, 2022; Monguillot Hernando et al., 2015). These procedures have shown several changes, from a static work with the maintenance of a muscle stretching position in a certain time (Castañer & Camerino, 2022; Jiménez-Parra et al., 2022), to a dynamic work with stretching and relaxation intervals (Lin et al., 2020). Within this type of dynamic flexibility, several methods have been implemented, such as performing it at maximum speed or ballistic, at controlled or dynamic speed or at resisted speed, known as "proprioceptive neuromuscular facilitation" (Merino-Marban, et al. 2021). The application of these procedures in sports has been debated over the last few years, as well as the order in which each one should be worked on during the training session (Donti et al., 2014).

In another field of application such as education, there has also been much controversy about the use of any of the methods in Physical Education classes at school age (Becerra Fernández et al., 2020; Castañer & Camerino, 2022). Their use and duration of stimulus or muscle stretching has also been discussed for decades in numerous researches (Ayala et al., 2012), and it has been concluded that it is preferable to use intervals of approximately 30 seconds (s) per muscle or muscle group, maintaining them in static stretching (STA), interspersed with intervals of 2 s of elongation and 1 s of relaxation for dynamic stretching (DYN) (Lin et al., 2020; Reid et al., 2018). The influence on the type of muscle elongation used and its reactive capacity has been investigated in recent years (Kirmizigil et al., 2014). In addition, it has been related to the strength and power produced in isoinertial exercises and variables related to the high jump or long jump (Kirmizigil et al., 2014). According to multiple research studies, the most suitable movement to measure lower limb power is the high jump compared to other types (Toumi et al., 2004). Within this, the countermovement jump or CMJ has shown a high relationship with performance in maximum, explosive or sprint strength tests (Markovic et al., 2004).

As devices to record the kinematic variables of these exercises have been used from linear transducers or encoders to measure force (N) and velocity (m/s) in exercises with external load (Morales-Artacho et al., 2018) to contact platforms to measure CMJ-related variables such as flight time (FT) and contact (CT) (s), jump height (HGT) in centimetres (cm), power in watts (W), and reactive strength index (RSI) (De Blas & González-Gómez, 2005). This variable is obtained from the quotient between the height (cm) and the CT (s) of the jump (Flanagan & Comyns, 2008). Its interpretation has been considered an indicator of optimal neuromuscular readiness to perform a jump (McBride et al., 2008), as a result of a rapid transition between concentric-eccentric phases of muscle contraction (Turner & Jeffreys, 2010) triggered by instantaneous nerve stimulation, which activates the locking of muscle fibre stretching organs such as the Golgi apparatus (Toumi et al., 2004). In this sense, the aim of the present research was to verify the possible differences in the variables obtained with the CMJ in students before starting Physical Education class using various flexibility methods.

Methodology

Participants

In this study, 105 participants from the three years (A, B, and C) of the first level of baccalaureate (1BAC) of the Secondary School IES Haygón in Sant Vicent del Raspeig were recruited. Of the 100% (105) participants, 86 (81.9%) took part in the study with an age of 16.74 ± 0.19 years, a mass of 65.17 ± 30.03 kg, a height of 1.71 ± 0.09 m and a body mass index (BMI) of 22.31 ± 8.61 kg/m^2. This group of participants consisted of 41 boys (16.74 ± 0.20 years, 75.72 ± 38.37 kg, 1.71 ± 0.06 m and a BMI of 23.60 ± 11.23 kg/m^2) and 45 girls (16.76 ± 0.20 years, 56.48 ± 9.48 kg, 1.63 ± 0.04 m and a BMI of 21.21 ± 3.92 kg/m^2).

The 86 participants who took part in the study met the following inclusion criteria: 1. participate in all the sessions of study design; 2. not have any cardiac, musculoskeletal, orthopaedic, or congenital disability that would prevent them from performing the jumps; and 3. have signed the informed consent permission of their legal guardians regarding the objectives, procedure, and risks of the study. The 19 participants who did not take part in the study did not meet any of the above criteria. This study was approved by the centre's management and the legal guardians of the participants, who signed the above-mentioned informed consent form. In addition, it complied with the current protocols of the Declaration of Helsinki on Ethical Principles for Human Research (World Medical Association, 2022). The intervention was carried out in the same time slot (10:00 - 12:00 AM UTC + 1) and with the same environmental conditions (15-19 °C) in the indoor gymnasium of IES Haygón.

This sample size was determined *a priori* using the G*Power software version 3.1.9.6 for Mac OS X 13. An ANOVA for repeated measures between factors and an analytical power type was estimated with the F-test family *a priori*. This test determined that, for a median effect size F of 0.25 (η_p^2 = .06), an alpha(α) < .05, statistical power(β–1) > .95, 3 groups, 3 measures (1 each participant and condition) and an option specification for SPSS, a minimum total sample of 168 participants (56 per condition) was required.

Study design

This research was based on a quasi-experimental intrasubject design (repeated measures) with a control condition. In order to evaluate the effect of dynamic muscle stretching interventions vs. static on countermovement jumping (CMJ) performance, each participant was subjected to the 3 intervention conditions: 1. without any application of stretch (CON), 2. static flexibility (STA) and 3. dynamic flexibility (DYN). These were assigned to each group-class with the following arrangement: 1BAC-A started the intervention with CON, followed by STA, and ending with DYN. For group 1BAC-B, the order was DYN, CON, and STA, respectively. Finally, for the third group (1BAC-C), the organisation was set up in: STA, DYN, and CON. In this sense, in each session, the starting order of the intervention was mixed up by its number on the PE teacher's list. This was done using the random sorting function of the Microsoft Excel (v. 11.0) spreadsheet programme developed by Microsoft (USA) for MacOS.

Procedure

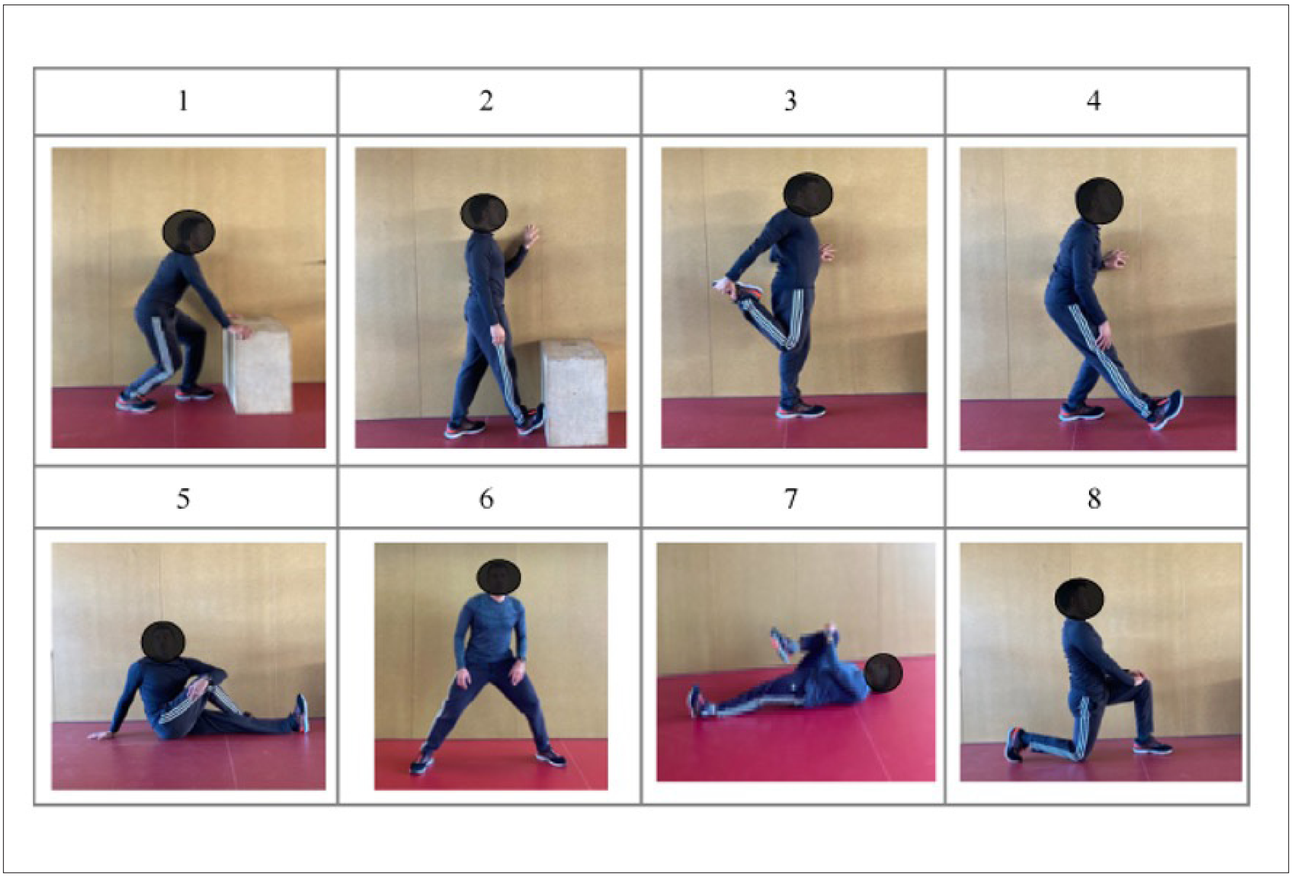
The timing of this intervention consisted of 5 sessions separated by a minimum of 48 hours for each group (1BAC-A, B, or C). In session 1 (S1), the protocol of this research was explained and the informed consent form that had previously been distributed by the teacher to the students, together with the authorisation of the legal guardians, was signed and collected. S2 was used for familiarisation of the intervention protocol, where 5 attempts of the CMJ jump were practised with control from the sagittal plane by 2 observers (Blazevich, et al. 2018) (PE teacher of the group and the researcher of the present study) and feedback was provided to the students to try to get as high as possible with as little contact time as possible with the (deactivated) platform on each jump. The CMJ was initiated from an upright position with hands on hips, knees at shoulder width and heels in contact with the platform (Blazevich, et al. 2018). Immediately, participants performed a self-selected eccentric downward countermovement until their thighs were no lower than parallel to the ground, and then immediately performed the two-footed vertical jump (Samson et al., 2012). In this session (S2), the positions for the posterior stretches (DYN and STA) were also practised. In addition, the self-perception of walking at 50% (5 on a scale of 10) of the maximum perceived exertion for the activity prior to the application of the 3 conditions was internalised. From here, the intervention sessions began in randomised order (see Study Design).

Sessions of the CON, STA, and DYN conditions

All intervention sessions (CON, STA, and DYN) were composed of an activation performed by walking clockwise around the indoor volleyball court in the gym (18 x 9 metres) for 3 minutes at 50% of maximum perceived exertion (Blazevich et al., 2018). Then, in the CON condition, they remained seated for 10 minutes on a Swedish bench with both feet in contact with the floor and their shoulder blades in contact with the wall. In the STA condition session, 8 static muscle stretches were performed for the lower limbs as shown in figure 1 (Taylor, et al. 2009). These positions were held for 30 s of effective stretch at each point and 1 minute at both limbs (8 minutes of total stretch time) and, to change to the next, 20 s of transition was used (a total of 10:20 minutes of stretch plus transition time) (Taylor et al., 2009). However, in the DYN condition, the 8 positions shown in figure 1 were made in effective stretching sequences of 2 s with the same feeling of tightness as in the STA condition and 1 s of cessation of stretching. To achieve the same effective stretching time in each position (30 s), limbs (1 minute) and total time (8 minutes) as in the STA session. Simultaneously, 20 s of transition was also used to change to the next position, with 14:20 minutes of elongation plus transition (Lin et al., 2020). The start, end and transition time of the stretches was monitored with the iCountTimer application (RhythmicWorks Software LLP) for the Iphone 6 IOS 16.0 smartphone (Apple, Inc., Cupertino, California, United States). To intensify the acoustic control of the speaking time, the smartphone was connected via Bluetooth signal (Bluetooth Special Interest Group, Inc.) to a 2.4 GHz radio frequency, to an external wireless speaker Sony SRS-XE300 (Sony Group Corporation, Tokyo, Japan). Following (< 1 minute) the intervention procedures described in the CON, STA, and DYN sessions, they completed 5 CMJs on the contact platform (Chronojump, Bosco System, Barcelona, Spain) with a temporal resolution of 1 millisecond (ms) at a data collection rate of 1,000 Hz to record the dependent variables (see introduction). For the treatment of the data from the 5 CMJs, 4 jumps were selected, discarding the first or starting jump (Serrano-Ramon et al., 2023).

Figure 1

Static and dynamic stretching positions.



1. Stretching of the Achilles tendon. 2. Stretching of the calf. 3. Stretching of the quadriceps. 4. Stretching of the biceps femoris. 5. Stretching of the gluteus maximus. 6. Stretching of the groin. 7. Stretching of the lower back. 8. Stretching of the psoas.

Statistical Analysis

All data are expressed as mean (*M*) and standard deviation (*SD*). Before statistical analysis, the dependent variables (RSI, CT, HGT, and PO) were subjected to the Shapiro-Wilk test to check that they met the assumption of normality. The influence of CON, STA and DYN conditions on RSI, CT, HGT, and PO was then analysed with a repeated measures analysis of variance (RM ANOVA) with a total of 3 levels (i.e. CON, STA, and DYN). In this sense, Mauchly's test for sphericity was assumed; if this assumption was not met, the degrees of freedom and error were corrected using the Greenhouse-Geisser or Huynh-Feldt approximations, respectively. In addition, the observed power was calculated as β -1, and the effect size (ES) was expressed by partial eta squared (η_p^2), and was set at: .01 as a small effect, .06 medium and .14 or higher as a large effect size. To analyse the comparisons for each of the 3 levels, a *post hoc* Bonferroni test was performed, and the significance level was set at $p < .05$, as well as reflecting the upper and lower limits of the 95% confidence interval [CI]. The analyses described above were carried out using statistical analysis software (SPSS Inc., Chicago, Illinois, USA).

Results

The results showed statistically significant increases in the RSI (see figure 2) with a median effect size $F_{(1.52)} = 20.21$, $p < .001$, $\eta_p^2 = .06$, β -1 = 1. In the capacity of DYN (*M* = 0.66, *SD* = 0.52) scores were higher than CON (*M* = 0.51, *SD* = 0.26, $p < .001$, [95% CI 0.07, 0.23]) and STA (*M* = 0.51, *SD* = 0.27, $p < .001$, [CI 95% 0.08, 0.23]). On the other hand, the CT (see figure 3) showed a significant increase in the STA condition (*M* = 0.45, *SD* = 0.19) with respect to CON (*M* = 0.41, *SD* = 0.15, $p < .01$, [95% CI 0.01, 0.07]) and DYN

($M = 0.39$, $SD = 0.16$, $p < .001$, [95% CI 0.02, 0.08]) with a small effect size $F_{(2.0)} = 8.58$, $p < .001$, $\eta_p^2 = .02$, β -1 = .97. In contrast, HGT (see figure 4) showed significant increases with a median effect size $F_{(1.97)} = 24.84$, $p < .001$, $\eta_p^2 = .07$, β -1 = 1, in the DYN condition ($M = 22.29$, $SD = 7.71$) with respect to STA ($M = 19.82$, $SD = 6.34$, $p < .001$, [95% CI 1.21, 3.72]) and CON ($M = 18.67$, $SD = 6.52$, $p < .001$, [CI 95% 2.28, 4.96]).

Figure 2
RSI values.

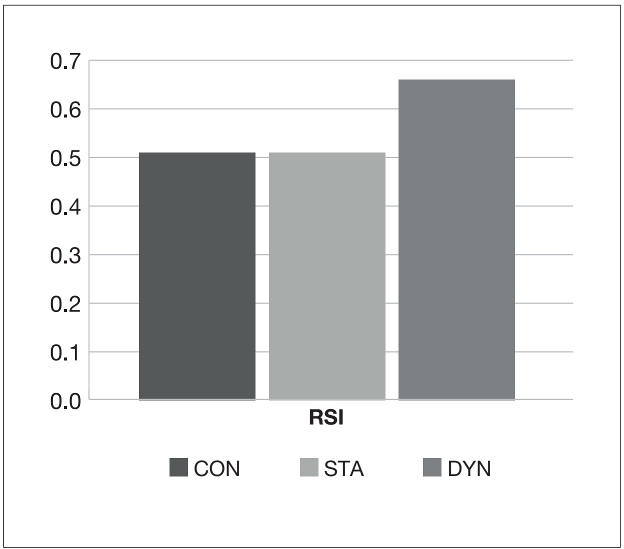


Figure 3
CT values.

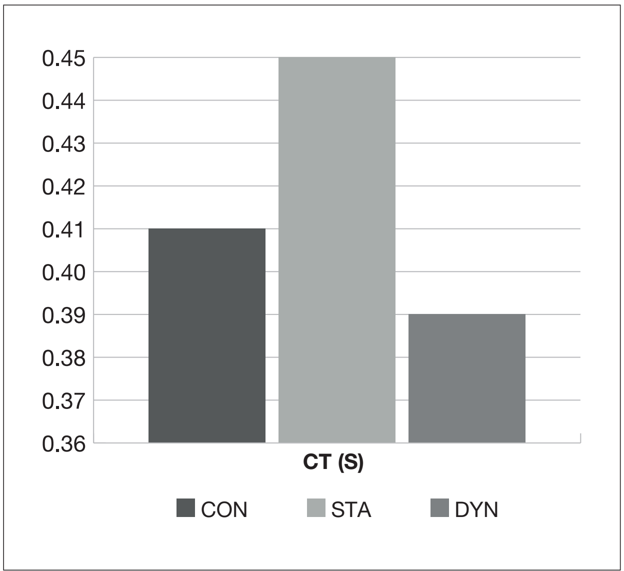
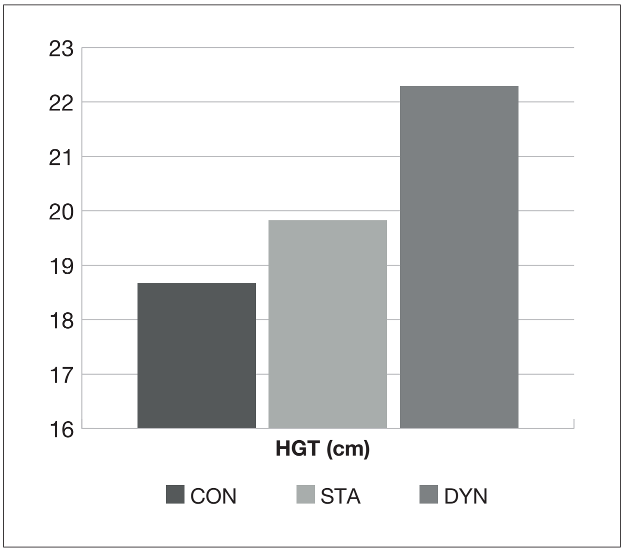


Figure 4
HGT values.



Discussion

The aim of this research was to test the acute effect of 2 muscle stretching procedures (static vs. dynamic) in comparison with the resting state (control), on the performance of the CMJ test among Physical Education students in the stage of their first year of baccalaureate. The results of the present study showed significant improvements in relation to CMJ performance on the dependent variables (RSI, CT, HGT) with the dynamic elongation condition, versus static and at rest. Procedures similar to this intervention have been investigated in a large number of papers over the past decades (Lin et al., 2020; Reid et al., 2018; Taylor et al., 2009). However, the RSI variable has been analysed in fewer studies compared to the other variables (CT, HGT, and PO) and treatments (STA vs. DYN) (Montalvo & Dorgo, 2019; Warneke et al., 2022; Werstein & Lund, 2012). In this sense, the RSI has shown increases in the research of Werstein and Lund (2012) in line with our results, although with differences in the methodological procedure. Starting with the fact that the participants in Werstein and Lund's (2012) research performed the RSI measurement using the drop jump from a 45cm box (Ruffieux et al., 2020), as well as significantly exceeding the pre-treatment activation time (10 vs. 5 minutes) and cycling on a cycleergometer rather than walking (Lopez-Samanes et al., 2021). In reference to the treatment, Werstein and Lund (2012) used the same elongation time in the STA condition as ours (30 s vs. 30 s), but in half as many positions as in this one (4 vs. 8). In contrast, in the DYN condition they did 3 sets of 10 repetitions without indicating the total duration time (Pinto et al., 2014). Interestingly, despite the methodological differences between the two studies, the significant increases in RSI coincided in the CON vs. DYN and STA vs. DYN. According to Stewart et al. (2003)

and Werstein and Lund (2012), the improvement of RSI could be due to the increase in conduction velocity and activation of the muscle fibres involved in the jumping action (Lopez-Samanes et al., 2021), as a consequence of the increase in muscle temperature caused by the dynamic activity. Interestingly, this hypothesis put forward by numerous investigations (Kirmizigil et al., 2014; Lin et al., 2020; Merino-Marban et al., 2021; Werstein & Lund, 2012) partially coincides with our results although the RSI is lower in the work of Werstein and Lund (2012) relative to the present (10.70 vs. 22.70%) in CON vs. DYN, since in this study no displacement was performed in the DYN condition (Wilczyńskiet al., 2021) and the activation time was shorter (10 vs. 5 minutes) (Lopez-Samanes et al., 2021) and would be more in line with Young's (1995) theory. This hypothesis is based on the interaction of the internal contractile and non-contractile structures of skeletal muscle in the stretch-shortening cycle (Turner & Jeffreys, 2010), which could be slowed down by the action of prolonged (≥ 30 s) muscle elongation (Takeuchi et al., 2021; Warneke et al., 2022). However, research by Montalvo and Dorgo (2019) and Warneke et al. (2022) registered no significant improvement in the RSI variable. This difference in results with the work of Montalvo and Dorgo (2019) could be due in the first place to the difference in the type of jump (in depth from a height of 30 cm vs. CMJ) (Ruffieux et al., 2020), to the lower number of CMJ compared to the present (2 vs. 5) (He et al., 2022) and to the performance of the jumps after the warm-up in a time of 3-5 minutes, much longer than ours (<1 minute) (Tsurubami et al., 2020). Since the total number of exercises targeting the lower limbs and the time spent on muscle stretching for each condition (STA and DYN) would be identical. In this regard, the research by Warneke et al. (2022) also had some methodological differences compared to this one, such as doing the stretching exercises on the plantar flexors and extensors and not on the rest of the muscle groups of the lower limbs. Since the number of jumps was the same, 1-minute pauses were incorporated between each attempt that could have conditioned the RSI result (He et al., 2022).

With regard to the variable CT, a significant increase in the STA condition was recorded in this study compared to CON and DYN. These results differ from those obtained by Werstein and Lund (2012), in which no differences were obtained in any condition, possibly justified by the relationship with the previous methodological differences provided in the RSI variable. This statement could be justified by the fact that CT is a component of RSI and the negative influence of STA condition with CMJ performance (Takeuchi et al., 2021; Warneke et al., 2022). Likewise, Young and Behm (2003) supported the rationale put forward by Werstein and Lund (2012), showing no differences in the CT score in any condition, although they had some distinctions such as jumping in depth (30 cm), activation performed by running and not walking and fewer muscle stretching exercises than in the present work (4 vs. 8). In line with our result, Lima et al. (2018) obtained significant decreases in CT with the STA condition compared to CON (8.55% vs. 10.97%), using the same static stretching time (30 s), number of CMJs, but with fewer positions (6 vs. 8).

Another variable related to CMJ and associated with multiple investigations comparing CON, STA and DYN conditions is HGT. Our results have shown significant increases in DYN compared to the rest (CON and STA). In this regard, the work of Montalvo and Dorgo (2019) also found significant improvements with HGT in DYN vs. STA (8.24%) lower than ours (11.08%). Despite some methodological differences, such as a reduced number of CMJs (2 vs. 5), which could lead to this difference in results between studies (He et al., 2022). Regarding the differences between CON and STA, our results do not coincide with those shown by Pinto et al. (2014). Specifically, because they found no difference between CON and STA with an elongation of 30 s, as it was established in the STA condition with a stretching time of 60 s, showing a reduction of -3.40%. This is in contrast to our research, which recorded increases of 5.80% in the STA condition vs. CON. The reduction in HGT between STA 60 s vs. CON was -3.40%, taking into account that in the study by Pinto et al. (2014) made fewer CMJs compared to ours (3 vs. 5); in addition, 10 s were recovered between each CMJ, fewer exercises were performed (4 vs. 8) and a different warm-up in the CMJ (5 minutes seated vs. 5 minutes walking). The performance of a lower number of CMJs and interspersed pauses could be one of the factors causing the difference in results between studies (He et al., 2022), together with the static activation procedure that could impair subsequent performance in the CMJ (Tsurubami et al., 2020), by not achieving an optimal temperature for muscle contraction (Lopez-Samanes et al., 2021).

In this regard, the results of Yildiz et al. (2020) also found improvements in HGT between CON vs. STA different from ours (10.38% vs. -5.80%). Although these studies showed procedural differences compared to this one, such as higher activation before the intervention (5 minutes of running plus 2 minutes of walking vs. 5 minutes), less stretching exercises (5 vs. 8) and number of CMJ (3 vs. 5 The causes of lower HGT in the CON condition vs. STA of our work could be due to the superior CT of the STA condition vs. CON needed to achieve more HGT (Takeuchi et al., 2021; Warneke et al., 2022), since the levels of the variable CT in the two conditions (STA and CON) are identical. In line with our results, the present study follows in many methodological aspects Taylor et al. (2009), such as the same exercises (8), the duration of stretching (30 s) and the total time in the STA condition. Despite some differences, such as pre-activation with a 300 m run at an underwater intensity and different and more numerous stretches in the DYN treatment (16 vs. 8). In addition to running or jogging for 20-30 m, use a time similar to the present time (15 vs. 14 minutes), without specifying the elongation-relaxation time and only performing 1 CMJ, as the work of Taylor et al. (2009) found lower results than ours between STA vs. DYN (4.20% vs. 11.08%). The causes of these differences could be due to the submaximal running activation prior to the CMJ (Tsurubami et al., 2020), the higher number of exercises in the DYN treatment (Young & Behm, 2003), or the single CMJ performed (He et al., 2022).

Consequently, the results of the present work have shown improvements in the variables that determine performance in the CMJ in the DYN condition, compared to the rest (STA and CON). In this sense, one of the reasons that could explain this positive influence of DYN treatment without displacement in comparison with the rest of the studies consulted would be the stretch theory of Turner and Jeffreys (2010), in which the maintenance of elongation of a muscle structure momentarily delays the effectiveness of the subsequent contraction, caused by the movement of the cross-bridges away from the sarcomere (Turner & Jeffreys, 2010). Related to this theory, Ettema et al. (1992) proposed the hypothesis of inhibition of muscle spindles and reduction of the contractile properties of muscle tissue as a consequence of the locking reflex of these structures (Ettema et al., 1992). However, it is not possible to conclude the theory responsible for the improvement of CMJ in the DYN condition, although in the other conditions it could be stated that a muscle elongation of ≥ 30 s or its absence decreases the performance in the CMJ test.

Conclusion

From the results obtained, it can be concluded that an acute programme of dynamic stretching appears to produce beneficial effects on countermovement jumping (CMJ) compared to no stretching or a 30 s maintenance of muscle elongation. This improvement occurred in all the variables analysed and showed significant differences. Thus, in the RSI variable, the DYN condition showed significant increases that were a representative value of the reactive jumping ability coupled with contact time (CT), which was significantly lower, and jump height, which was significantly higher in DYN. According to the literature consulted, it is the set of the above variables that provides valuable information on the reactive capacity of the lower limbs in countermovement jumping.

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