STRATEGIES TYPES ON PRECEDENT VERTICAL JUMP STRETCHING

ESTRATÉGIAS SOBRE OS TIPOS DE ALONGAMENTOS QUE PRECEDEM O SALTO VERTICAL

ESTRATEGIAS SOBRE LOS TIPOS DE ESTIRAMIENTOS QUE PRECEDEN AL SALTO VERTICAL

Systematic Review
Revisão Sistemática
Revisión Sistemática

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ABSTRACT

Study design: identify a better strategy for static stretching (SS), dynamic stretching (DS), and proprioceptive neuromuscular facilitation (PNF) concerning the performance of their applications in countermovement vertical jump (CVJ). A systematic literature review was conducted in May and June 2021 in the Pubmed/MEDLINE, Scopus, LILACS, SPORTDiscus, and Embase databases. The PRISMA-2020 checklist was used. The Cochrane handbook scale and the Downs and Black scale were used for risk of bias analysis. Seventeen studies were included for qualitative analysis. Motor Unit recruitment and its stimulation frequency favor neural factors and muscle strength performance during contraction. Detailed investigations are necessary on the neural factors that modify the reflex responses and motor control, considering the biological characteristics and plastic deformations. The SS is a negative predictor of vertical jump (VJ) performance. The improvements are reduced when the stretching time is longer than 60 seconds, and when associated with PNF, did not reveal significant results. Using the SS before the DS in short periods of 20 seconds and no more than 60 seconds in the pre-activity to the VJ is suggested. In short stretches, the ROM increased both in the knee and the hip, and the hamstring muscles, when in tension, are unfavorable in sports that frequently use the VJ. Therefore, PNF using the technique that involves a process of contracting and relaxing must be investigated in an isolated and specific way, advocating the antagonist group. Thus, decreasing antagonist strength may be favorable for height gain, although contemporary studies are needed to minimize lower stability and muscle control predictors. ***Level of Evidence II; Systematic Review Study.***

Keywords: Amplitude; Volleyball; Muscle Stretching Exercises; Muscle Strength; Physical Functional Performance.

RESUMO

Design do estudo: identificar uma melhor estratégia de alongamento estático (AE), Alongamento dinâmico (AD) e facilitação neuromuscular proprioceptiva (FNP) em relação ao rendimento de suas aplicações no salto vertical contramovimento (SCM). Desenvolveu-se uma revisão sistemática da Literatura nos meses de maio e junho de 2021, nas bases de dados Pubmed/MEDLINE, Scopus, LILACS, SPORTDiscus e Embase. Utilizou-se o checklist PRISMA-2020. Para análise de risco de viés utilizou-se a escala do Cochrane handbook e a escala de Downs and Black. 17 estudos foram incluídos para análise qualitativa. O recrutamento da Unidade Motora e a sua frequência de estimulações favorecem os fatores neurais e o desempenho da força muscular durante a contração. Investigações circunstanciadas são necessárias sobre os fatores neurais que modificam as respostas reflexas e controle motor considerando as características biológicas e deformações plásticas. O AE é um preditor negativo para o desempenho do salto vertical (SV) e, as melhorias são reduzidas quando o tempo de alongamento é superior a 60 segundos, e quando associado a FNP não revelou resultados significativos. Sugere-se a utilização do AE antes do AD em períodos curtos de 20 segundos e não mais que 60 segundos na pré-atividade ao SV. Nos alongamentos curtos a gama de movimentos aumentou tanto no joelho quanto no quadril e, a musculatura isquiotibial, quando em tensão, é desfavorável em esportes que utilizam frequentemente o SV. Portanto, a FNP com a utilização da técnica que envolve um processo de contrair e relaxar deve ser investigada de forma isolada e específica preconizando o grupo antagonista. Desta forma, diminuir a força do antagonista pode ser favorável para o ganho de altura, embora estudos atualizados sejam necessários para minimizar os preditores de menor estabilidade e/ou controle muscular. ***Nível de evidência II; Estudo de Revisão Sistemática.***

Descritores: *Amplitude; Voleibol; Exercício de Alongamento Muscular; Força Muscular; Rendimiento Físico Funcional.*

RESUMEN

Diseño del estudio: identificar una mejor estrategia de estiramiento estático (EE), estiramiento dinámico (ED) y facilitación neuromuscular propioceptiva (FNP) en relación con el rendimiento de sus aplicaciones en salto vertical con contramovimiento (SCM). Se realizó una revisión sistemática de la literatura en mayo y junio de 2021, en las bases de datos Pubmed/MEDLINE, Scopus, LILACS, SPORTDiscus y Embase. Se utilizó la checklist PRISMA-2020. Para el análisis del riesgo de sesgo se utilizaron la Cochrane handbook y la escala de Downs y Black. Se incluyeron 17 estudios para el análisis cualitativo. El reclutamiento de Unidad Motora y su frecuencia de estimulación favorece los factores neurales

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y el desempeño de la fuerza muscular durante la contracción. Son necesarias investigaciones detalladas sobre los factores neurales que modifican las respuestas reflejas y el control motor considerando las características biológicas y las deformaciones plásticas. El EE es un predictor negativo para el rendimiento de la salto vertical (SV) y las mejoras se reducen cuando el tiempo de estiramiento es mayor a 60 segundos, y cuando se asocia con FNP no revela resultados significativos. Se sugiere utilizar el EE antes del ED en periodos cortos de 20 segundos y no más de 60 segundos en la preactividad al SV. En tramos cortos, la gama de movimientos se incrementó tanto en la rodilla como en la cadera, y los músculos isquiotibiales, cuando están en tensión, son desfavorables en deportes que utilizan frecuentemente el SV. Por tanto, la FNP mediante la técnica que implica un proceso de contracción y relajación debe investigarse de forma aislada y específica, preconizando el grupo antagonista. Por lo tanto, la disminución de la fuerza del antagonista puede ser favorable para la ganancia de altura, aunque se necesitan estudios contemporáneos para minimizar los predictores de menor estabilidad y/o control muscular. ***Nível de Evidencia II; Estudio de Revisión Sistematica.***

Descriptores: *Amplitud; Voleibol; Ejercicios de Estiramento Muscular; Fuerza Muscular; Rendimento Físico Funcional.*

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INTRODUCTION

Volleyball is a sport where the athlete's vertical jump (VJ) is paramount. In a volleyball match, an average of 170 to 190 jumps are developed to establish a good performance and jump quality that demands a learning period.[1] The volleyball player's VJ performance is associated with his lower limb strength and speed, which in turn is establrough an orderly arrangement of dynamic ballistic actions and stretches in specific muscle tissues.[2] Training athletes who warm up with stretching and jumping, associated or not with the use of weights, has shown a positive effect on the gain of height and speed of the VJ.[3]

Stretching emerges as an option for the physical development of these athletes, since it is established as a specific exercise that interferes with the soft tissues, increasing their length and flexibility.[4] There are, however, controversies to changes in the mechanical properties of the muscle tendon after stretching steps.[5-7] Similarly, submaximal stretching before the vertical impulsion test demonstrated lower power of the specific lower limb muscles.[8]

Different methods are being improved with the purpose of making the most of the athlete's potential. Resistance training for the respective lower limb muscle groups is becoming established as an intention in the vertical jump height gain, such as load control in training, load organization models, and motor skill development.[9] Recent studies have investigated different methodological targets for sports activities in which the jump confers a direct association with its performance, considering aspects related to the evaluations of physical valences, kinetic asymmetry, and the compromising of its dynamics.[10-12]

The lack of muscular preparation for speed and ground force may reduce vertical impulsion and power, thus requiring more specialized training.[13] Physiological factors are still discussed in the scientific community from various aspects. Among others, the effects of static stretching (SS), dynamic stretching (DS), proprioceptive neuromuscular facilitation (PNF), and even on the effects of muscle interference in jumping, as well as phosphorylation of the myosin regulatory light chain, the affinity for calcium ($Ca2+$) to troponin and increased recruitment.[14-16]

Factors such as body mass index (BMI), fat percentage, and the impact of the athlete's psychological state should be considered, as they can negatively affect jump power.[6,17,18] Therefore, understanding the mechanisms that underpin the increase or loss of force subsequent to a stretching technique clarifies the differences in results between scientific research and contemporary strategy development. Thus, the study aims to identify the biomechanical aspects on the SS, DS, and PNF and the possibility of a better performance of their applications in the VJ countermovement.

METHODS

A systematic literature review was developed with a literature search source using a flow chart based on the PRISMA checklist.[19] A protocol involving an evaluation report with different scientific studies was organized.

Eligibility Criteria

Through a pre-established protocol, the studies should contain the aspects related to the relationships of stretching muscle groups with the VJ. There was no restriction or limitation on publication year and language. For qualitative analysis, quantitative experimental studies and observational cohort, cross-sectional, and case-control studies were recommended. Quasi-experimental studies with strong alignment and review impact would not enter the qualitative analysis but could be included only in highly relevant cases just to enrich the research through specific information. The same procedure was adopted with regard to methodological research containing strategies for searching scientific literature and methods for developing review studies. Other writings contained in editorials, personal opinions, comments, newspapers, letters, primers, and congress abstracts were not considered for this research. Studies with other sports would only go in to clarify muscular physiological issues of relevance, but would not enter into the qualitative analysis.

The exclusion factors were established as follows: the VJ that was not equivalent to the biomechanics of volleyball, basketball, or soccer would not be considered; the population of the studies should be athletes older than 15 and younger than 35; the research should present the specific characteristics of the actions of this sport involving the analysis of the jump in combinations of acceleration and deceleration during the movement action, as well as the stretching techniques applied in the pre-action.

Regarding the topics of interest, they should contemplate all chemical, mechanical, and physiological aspects during the movement of the VJ with priority to volleyball. However, we considered the vertical jump of basketball and soccer in order to investigate the outcomes of the different stretching techniques. The VJ movement involves an eccentric action followed by a concentric one, where the athlete will start in the standing position, make a downward movement with flexion of hips, knees, and ankles, and then extend them in an VJ over the ground surface.

Information Sources

PubMed/MEDLINE, *Scopus*, Latin American and Caribbean Literature on Health Sciences (LILACS), SPORTDiscus, and Embase databases were used to obtain keywords. The reference list of the included studies was reviewed manually to assess the importance of including additional references.

Research Strategy

The search for the descriptors was performed on May 4, 2021. The descriptors *Amplitude, Volleyball, Muscle Stretching exercise*, Muscle strength, Phisical functional performance, associated with the Boolean operators "AND" *and* "OR",were selected inorder to acquire studies more adherent to the pre-established theme. For all sites the same search strategy was used: "Amplitude" AND "Volleyball" AND "Muscle Stretching Exercises" AND "Muscle Strength" AND "Physical Functional Performance"; "Amplitude" OR "Volleyball" OR "Muscle Stretching Exercises" OR "Muscle Strength" OR "Physical Functional Performance".

This research was aided through the PICO strategy.[20] Thus, the population of interest included volleyball, basketball, and soccer athletes. The intervention was the studies with conceptions of analysis concerning the physiological and biomechanical characteristics on the VJ. The comparison is not established through a direct conception. However, the present research indirectly verified the studies that addressed the physiological and biomechanical aspects after the development of strategies with stretching. The result was the search on the different outcomes containing percentage and systematic data after the application of stretching strategies for VJ performance.

Selection Process

The selection process was developed by peers following the recommendations of the PRISMA - 2020 consensus, guided by the following question: which stretching strategy enables better performance during VJ.

The search was developed by two independent reviewers, and in case of disagreement, a third reviewer mediated the inclusion process. It is worth noting that a protocol with pre-established criteria was developed, and although there was no year limitation for inclusion, the protocol gave preference to the most recent studies with the greatest strength of scientific evidence, advocating the internal validity of the research and the guidelines of the Centre for Evidence-Based Medicine, Oxfors, UK (www.cebm.net), which is similar to the pyramid guidelines of Murad et al.[21] In the first collection step, the EndNote X9.1 reference manager was used.[22]

Process of Data Collection and Data List

From the initial selection of publications, added to the chosen bases and the proposed criteria, the process of reference selection was applied for systematic reviews following the steps: identification of repeated works; descriptor reading; title reading; abstract reading; methodological analysis. Studies that did not present aspects related to VJ; different populations; methods and results not elucidated between stretching and its contribution to VJwould be excluded. The studies should contain the physiological and biomechanical aspects and the strategies used by the researchers.

Consecutively, the articles were submitted to a bibliometric analysis by the reviewers using Sitkis bibliometric software.[23] The purpose of this keyword cocitation analysis was to evaluate the frequency and interaction of the descriptors present in the selected articles. In this way, keyword analysis would allow a retrospective evaluation of the quality of the selection process of the articles used.

After rechecking the criteria and acquiring the articles to be used, the number of selected studies was reorganized into topics with the insertion of two themes pertinent to the study's objective:

• Performance from SS and DS on the factors related to VJ performance.
• Influence of different strategies with PNF and physiological and neuromuscular ability during VJ.

Association measures used

Experimental studies that used analyses of proportions using statistical tests such as chi-square and Fischer's exact test were considered. Likewise the verification of studies that used the *Shapiro-Wilk* test to verify the normality of the data and even strategies already used to verify the VJ outcomes. The significance levels in the different results were noted, which could be 5% ($p<0.05$) or 1% ($p<0.01$).

Assessment of the risk of bias in the selected studies

The two authors in the clinical trial studies followed the guidelines of the "Cochrane handbook for systematic reviews of interventions(Version 5.1.0).[24] With an adaptation of the Cochrane Handbook bias checking tool, the authors evaluated and considered the results as follows: it was considered satisfactory and of possible allocation when a given study reached " ≥4" domains of table 8.5.d (handbook-5-1.cochrane), with a low bias level. It is worth noting that in order to be selected, a given study should present a low risk of bias, preferably in domains six and seven, that is, a low level of bias superiority in four or more domains, provided that the sixth and seventh domains are included. It was considered unsatisfactory for this research when a study achieved "low risk of bias" in only one, two, or three domains "≤ 3".

In other types of studies, i.e., cohort, case-control, and cross-sectional studies, the level of bias was assessed by an adaptation of the "Downs and Black" scale.[25] This scale aims to assess studies unrelated to randomized clinical trials. The scoring for a given study to be allocated occurred as follows: for research to be selected it had to reach a minimum of 13 points, regardless of the type of study. However, the maximum score for case-control studies was set at 28 points according to the scale criteria and 22 points for cohort and cross-sectional studies.

RESULTS

In the databases selected for the article search, 10,615 articles related to the topic of interest were identified. After 7,146 duplicate articles were removed, 3,469 articles were obtained for analysis in Portuguese, English, and Spanish. A comprehensive title and abstract analysis eliminated 3,032 articles, resulting in 437 articles. Subsequently, articles excluded based on the PICO question (n = 396). In the second stage, all 41 remaining articles were read in full and 24 were excluded from the analysis; four did not present data to identify the strategies used in the performance of the vertical jump, 11 evaluated other results, and nine presented insufficient association data to evaluate the physiological and biomechanical aspects in relation to the stretching strategies. The flowchart showing the identification, inclusion and exclusion process in more detail in Figure 1.

Subsequently, the interaction of the descriptors present in the selected articles, as shown in Figure 2.

Research general related-characteristics to type of study and the country where has been developed

The present systematic review included 17 scientific studies for qualitative analysis after applying the selection matching the criteria mentioned above, of which 15 (88.2%) were experimental studies and two (11.7%) were cross-sectional studies. Regarding the country where the studies were developed: four (23.5%) were developed in the United States of America, three (17.6%) in the United Kingdom, three (17.6%) in Brazil, two (11.7%) in Australia, one (5.9%) in Costa Rica, one (5.9%) in Colombia, one (5.9%) in Canada, one (5.9%) in Greece, and one (5.9%) in Turkey. (Table 1)

Absolute sum of the data relative to survey numbers and scores achieved

With regard to the scores on the adapted Downs and Black scale, two cross-sectional studies achieved the desired score. One study reached thirteen points and one reached fourteen points. Using the

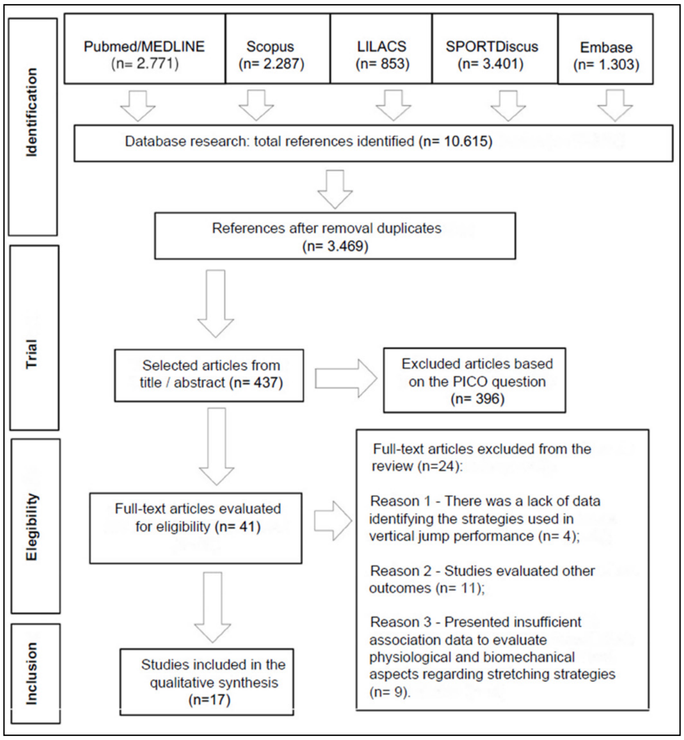

Figura 1. Flowchart of the selection process for the literature search; the diagram checklist (PRISMA 2020).

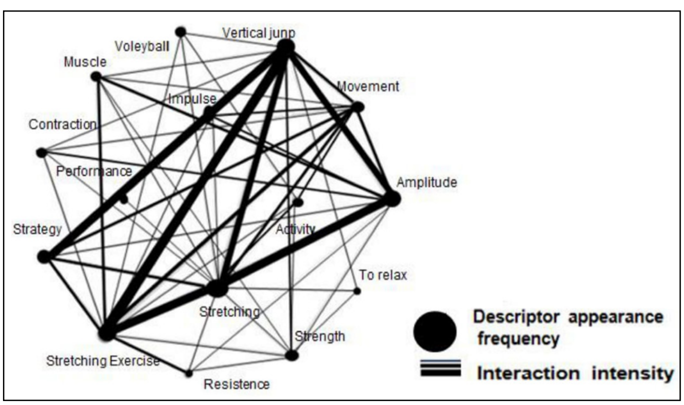

Figura 2. Interaction analysis of the most relevant keywords. Software Sitkis (Schildt, 2002).

Cochrane Handbook tool, five experimental studies had low risk of bias in five (5) domains, which was the most significant proportion of the low risk of bias, and ten scientific trials achieved low risk of bias in four (4) domains. (Table 2)

DISCUSSION

Performance from SS and DS on factors related to VJ performance

EA is often used in clinical and athletic settings with the specific goal of increasing joint range of motion (ROM) and reducing injury risk.[26] Stretching-induced loss of force appears to have a strong impact on muscle length, and the viscoelastic effects of stretching allow for an increase in joint ROM, which, in turn, are associated with decreases in passive stretching resistance.[27] However, after a certain duration of stretching resistance at the same ROM, the consequence points to a reduction in force.[27]

Different findings occurring between the years 2000 and 2021 pointed to the SS at different execution times as a maneuver that predisposes to decreased jumping performance.[28-32] The morphological aspects as well as the strength and compliance relationships of the musculature suggest more specific investigations for the performance of the VJ. Studies have shown a marked -10.2% loss of muscle strength in muscles of short muscle lengths in contrast to a +2.2% gain in muscles of longer muscle lengths.[33,34] While some authors have looked at the relationships of muscle compliance with muscle contraction time and strength analysis, others have focused on the neural action of the muscle and the consequences regarding attenuation of reflex activity and unfavorable torque outcomes.[7,35]

Researchers examined the effects of single-series SS, PNF and DS on VJ height and hip and knee ROM. As for the dose-response effect related to time, there were no significant values when a stretch of <60 s was applied.[36] According to the systematic values there is no association of improvements in the relationships between SS and power after short stretches, and when the time was ≥60 s, there seems to be an even lower probability of performance - 4.6%.[36]

The associated SS and DS over a 20-second period before the VJ indicated improvements in mean VJ height by 1.8% in SS and 2% for DS. However, it showed no difference between the groups ($p > 0.017$). As for knee and hip ROM in male athletes, both groups with SS and DS increased the ROM of the hip by 4.7% and 6% and of the knee by 1.7% and 0.02%, respectively.[36] Stretching time assumes to be a fundamental factor indicating small improvements in the VJ when its development was of short duration.[37,38]

In routine volleyball, the relationship between optimal protocol and higher performance is not yet elucidated in the literature. A study in 2021 investigated, using two protocols, the acute and long-term effect through SS of equal duration and period.[31] The strategy targeted hip hyperextension and height of countermovement heel (CVJ) with a control group for analytical design. There was no significant difference in the use of the two protocols in subsequent comparison with the control group ($p>0.05$). With regard to ROM, the authors observed that long-term SS of long duration applied in single or multiple episodes of equal duration, results in acute and long-term improvements.[31]

Stretching time had an impact on the evidence of a muscle strength-related effect. In knee flexors (<60 seconds (s), -4.8%; ≥60 s, -6.4%), plantar flexors (<60 s, -3.5%; ≥ 60 s, -5.9%) and knee extensors (<60 s, -2.6%; ≥ 60 s, -3.8%).27,33,34 SS showed positive effect only for sprinting in volleyball athletes, but passive passive static stretching (PSS) and running did not show positive results in this type of test.[39,40]

About the DS, the technique differs from the SS specifically by the whole-body movement involving one or more muscle groups and is established through a sequence of rhythmic active contractions that consecutively will adapt to the functional range of motion. In the sports scenario, there is a preference for DS due to the following aspects: it facilitates the preparation of the activity, increases the speed of nerve conduction, raises central temperature, activates muscle compliance and the enzymatic cycle accelerating energy production.[41,42]

It is important to comment on the increase in dynamic activity using the DS compared to the SS, since it tends to decrease the performance of the jump.[42] Regarding the DS and ballistic stretching (BS), the highest frequency was evidenced in both the DS and the BS, and these can be included in the strategies of VJ.

Techniques with DS offer neurophysiological changes that correspond to a stretching using impulse in an attempt to exceed normal ROM.[41,43] Such dynamics tend to increase afferent impulses from the spindle reflex and neurons may subsequently affect performance.[43]

In a pre-activity to CVJ, performance was more favorable after a maximal run than an PSS.[44]

Stretching was presented as a favorable prognostic factor regardless of its frequency. Scholars have shown that dynamic leg swings at (100 - min - 1) resulted in CVJ and drop jump heights with percentages of

Table 1. Strategies and characteristics of the studies selected in the analysis.

Author/Year/Country	Number of participants in the sample/ Strategies used
Hespanhol et al.[1] 2006 (Brazil)	n= 18. The variables of PP, MP and FI were studied through VJ tests with 4 sets of 15s and 10s of recovery. The collection through the descriptive technique and the JRC. The performance variables with intermittent effort were estimated using the JUMP TEST contact mat, stadiometer for anthropometric measurements, and an electronic scale. CVJ was performed 60 seconds after the end of the warm-up.
Gómez-Álvarez et al.[3] 2020 (Costa Rica)	n= 13. three different protocols. DS race, race, DSJ, and finally race. DS and jumps loaded with 8% of body weight. Evaluation: CMVJ, HJ, and 20-meter timed speed test. 4-week period, 2 to 3 times a week and a 48-hour rest period. The time required to perform a 20 m Sprint was also measured.
Konrad et al.[7] 2019 (Austria)	n= 14. Four test days with three different rest times (0.5, 10 min) after 5 × 60 s of stretching or after a control period without stretching. ROM), TPR and CVM were measured with an isokinetic dynamometer. Muscle activity was monitored by EMG (myon 320, Switzerland). Ultrasound at 25 Hz. The videos synchronized and digitized in VirtualDub software and analyzed in software (ImageJ). Use of ultrasound and 3D kinematics with reflective markers and four VICON® cameras.
Konrad et al.[8] 2010 (Brazil)	n= 20. Three vertical jumps on Contact platforms (Multisprint). Anthropometric measurements of body mass and height were obtained using a digital scale with a stadiometer. Two contact plates and the Multisprint 1.20 software were used for the jumps. Warm-up of 5 min at submaximal intensity (60 to 70% of maximum heart rate) on a cycle ergometer To evaluate the perception of effort in the SS, use of the PERFLEX method.
Kirmizigil, Ozcaldiran and Colakoglu[14] 2014 (Turkey)	n= 100. Aerobic warm-up (5 min run) followed by BS (5 s for each stretching exercise), PNF + BS (PNF performed followed by 5 s of BS), and PNF+ SS (PNF performed followed by 30 s of VJ) treatment protocol respectively on the same day. 4 sets bilaterally. The muscles: lumbar extensor, gluteus maximus, and hamstrings were stretched with a single stretching exercise. After 2 min rest, 3 VJ trials and one of the treatment protocols.
Bradley, Olsen and Portas[16] 2007 (United Kingdom)	n= 18. We set up 4 different conditions in a random order, on different days, interspersed with a minimum of 72 hours rest. Each session consisted of a standard 5 min warm-up cycle, accompanied by one of the following conditions: (a) CG, (b) 10 min SS, (c) 10 min BS, or one min PNF. The subjects performed 3 trials of static jumping and CVJ and post-stretching at 5, 15, 30, 45 and 60 minutes.

Abbreviations: BS - Ballistic Stretching; DS - Dynamic Stretching; SS - Static Stretching; ROM - Range of Motion; DSJ - Dynamic Stretching with Jump; SS - Static Stretching; ICC - Intraclass Correlation Coefficient; PNF - Proprioceptive Neuromuscular Facilitation; HZ - Hertz; CMVJ - Counter Movement Vertical Jump; FI - Fatigue Index; PERFLEX - Perceived Effort Scale in Flexibility; AM - Average Power; PP - Peak Power; HJ - Horizontal Jump; VJ - Vertical Jump.

Author/Year/Country	Number of participants in the sample/ Strategies used
Villaquirán et al.[17] 2020 (Colombia)	n= 14. Anthropometric measurements, vertical and lateral unipodal jumping tests on a contact platform, and assessment of vastus medialis and vastus lateralis activation by surface electromyography with a sampling rate of 4,000 Hz per channel were performed. 2.4 GHz frequency and a constant latency of 16 m during testing and evaluation of iliotibial muscle flexibility using the Ober maneuver.
Behm and Kibele [29] 2007 (Canada)	n= 10. The subjects were pre-tested by performing two repetitions of three different stretches to assess ROM and two repetitions of five different types of jumps. After the pre-test, participants were stretched four times for 30 s each, with 30 s of recovery for the quadriceps, hamstrings, and plantar flexors at 100% to the point of causing discomfort 75% and 50% of the PNF or a control condition.
Dont et al.[31] 2020 (USA)	n=30. Stretching was performed three times a week for nine weeks. One leg performed repeated stretching (3 × 30 s with 30 s rest) while the other leg performed a single stretch (90 s). The CG trained normally. ROM and CMVJ were measured before and two min after stretching in the respective weeks. Markers at the hip, knee and ankle, recorded with a digital camera.
Murphy et al. [33] 2010 (USA)	n = 42 men (aged 18-24). In this study, a repeated measures design, subjects were randomly assigned into one of three groups: a 20 s DS group, a 20 s SS group, and a CG. Knee and hip ROM, sit and reach, and heel height were measured before and after the treatment condition using a plastic goniometer. The same measurements were performed on the control group that sat for 12 minutes. Everyone did a five-minute warm-up on a cycle ergometer. For measuring the maximum jump height. A Vertec vertical range meter (Power Systems, Knoxville, TN) was used. Anthropometric measurements were made with a standard medical beam stadiometer. Body fat percentage was determined by the skinfold method using the Jackson and Pollock equations.
Pulverenti et al.[35] 2019 (USA)	n= 20. The subjects were tested before and after 5 min (5 × 60 s stretches) of passive and intense SS of the plantar flexor muscles. Two protocols (A and B) were conducted. Transcranial magnetic stimulation was applied to the contralateral motor cortex at rest (Protocol A) and during MVC (Protocol B). The measurements with an isokinetic dynamometer. Television monitor. Recording synchronously at 2,000 Hz on a personal computer running LabChart software, and 16-bit analog-to-digital converter.

Abbreviations: BS - Ballistic Stretching; DS - Dynamic Stretching; SS - Static Stretching; ROM - Range of Motion; MVC - Maximum Voluntary Contraction; PNF - Proprioceptive Neuromuscular Facilitation; CG - Control Group; GHZ - Gigahertz; Hz - Hertz; CMVJ - Counter Movement Vertical Jump; POD - Point of Discomfort.

Author/Year/Country	Number of participants in the sample/ Strategies used
Alipasali et al.[39] 2019 (Greece)	n= 27. three groups: (a) the first doing DS three times a week, (b) the second following an SS protocol at the same frequency, and (c) the third (CG) without stretching. 6 weeks for all, with the initial and final field sprint test performed at 4.5 and 9 m. Each stretching exercise lasted 10 s and was repeated twice (2 × 10 s), 10 s interval between exercises, simultaneous work using one limb at a time.
Fletcher et al.[41] 2010 (United Kingdom)	n= 24. The subjects performed a standardized 10 min running warm-up followed by either stretching protocol: no stretching. Slow DS at 50 b/min or fast DS at 100 b/min. After the warm-up squats, CVJ and deep jumps were performed. Heart rate, tympanic temperature, electromyography (EMG) and kinematic data (100 Hz) were collected during each jump.
Solon Junior and Silva Neto[44] 2020 (Brazil)	n= 13. Two functional tests (CVJ and 10-meter Sprint). Three different conditions: 1) control condition, 2) after passive static stretching and 3) after a submaximal run. CVJ and Sprint performance were obtained via smartphone application, MyJump 2.0. Jump height, force, power and speed were calculated. The CVJ was recorded in 240 fps (frames per second) with a mobile device and the performance in the 10m sprint with the iOS smartphone app (SpeedClock).
Hough et al.[45] 2009 (United Kingdom)	n= 11 (age 21 ± 2 years). Subjects participated in 3 conditions (no stretching, static stretching, and dynamic stretching) on separate occasions in a crossover, randomized design. During each condition, measurements of vertical jump height (VJH) and EMG activity during the vastus lateralis were recorded.
Konrad, Gad and Tilp[48] 2015 (Austria)	n = 49. The subjects were randomly assigned to control and PNF stretching groups. Before and after the stretching intervention, the ROM was determined with the corresponding fascicle length and penetration angle. The TPR and the MVC of the muscle-articular complex were measured with a dynamometer. The displacement of the muscle-tendon junction allowed us to determine the length changes in the tendon and the muscle and therefore calculate the stiffness.
Gunn et al.[53] 2019 (USA)	n= 40. Study 1: Instrument-assisted soft tissue mobilization, n = 17 Study 2: PNF: n = 23. Hip flexion ROM was measured with a passive straight leg raise (for IASTM) or active straight leg raise (for PNF) before and after stretching. Participants performed a static self-stretch on one leg and received the alternative intervention on the contralateral leg. Flexion measurements were performed using an inclinometer.

Abbreviations: DS - Dynamic Stretching; ROM - Range of Motion; SS - Static Stretching; MVC - Maximum Voluntary Contraction; EMG - Integration of Electromyographic Records; PNF - Proprioceptive Neuromuscular Facilitation; CG - Control Group; IASTM - Instrument-Assisted Soft Tissue Mobilization; IE - Elasticity Index; CVJ - Counter Movement Jump; Sprint - Acceleration Capacity over a Short Distance; PRT - Passive Resistive Tapping.

Table 2. Observational and experimental studies from the adaptation of the Downs and Black and Cochrane Handbook scales.

Authors	Type of study	Cochrane Handbook SO/MS	Downs and Black SO/MS	Relative frequency (%)
Hespanhol et al.[1]	Experimental Study	4/7	–	57.1
Gómez-Álvarez et al.[3]	Experimental Study	4/7	–	57.1
Konrad et al.[7]	Experimental Study	4/7	–	57.1
Nogueira et al.[8]	Experimental Study	4/7	–	57.1
Kirmizigil, Ozcaldiran and Colakoglu.[14]	Cross section	–	13/22	59.1
Bradley, Olsen and Portas.[16]	Experimental Study	4/7	–	57.1
Villaquirán et al.[17]	Cross section	–	14/22	63.6
Behm and Kibele.[29]	Experimental Study	5/7	–	71.4
Donti et al.[31]	Experimental Study	4/7	–	57.1
Pulverenti et al.[35]	Experimental Study	5/7	–	71.4
Murphy et al.[36]	Experimental Study	5/7	–	71.4
Alipasali et al.[39]	Experimental Study	4/7	–	57.1

SO: Score obtained; MS - maximal score.

Authors	Type of study	Cochrane Handbook SO/MS	Downs and Black SO/MS	Relative frequency (%)
Fletcher et al.[41]	Experimental Study	5/7	–	71.4
Solon Junior and Silva Neto.[44]	Experimental Study	4/7	–	57.1
Hough et al.[45]	Experimental Study	4/7	–	57.1
Konrad, Gad and Tilp[48]	Experimental Study	4/7	–	57.1
Gunn et al.[53]	Experimental Study	5/7	–	71.4

SO: Score obtained; MS - maximal score.

6.7% and 9.1% respectively more than activities with DS at (50 - min - 1). Consecutively, comparing (50 - min - 1) with a no-stretching condition, the outcome was significantly higher by 3.6% even though a lower frequency was used.[41]

Studies on a combination of dynamic movements with slow and faster rates in the same routine before activity have shown improvements in VJ. A reduction in VJ performance after SS wakes up about the possibility of a neurological impairment and a possible change in the viscoelastic properties of the *muscle* tendon unit.[45] Increased VJ performance after DS, on the other hand, seems to be associated with post-activation potentiation. In the study by Sekir et al.[46] with similar DS techniques they characterized the potentiation process, and the outcomes showed increased values in the hamstrings, eccentric quadriceps and concentric torque (7% -15%).

Influence of different strategies with PNF and physiological and neuromuscular ability during VJ

PNF was started as a treatment method in the late 1940s by physician *Herman* Kabat and physiotherapist *Margaret Knott* with few changes until today in the sports scenario and in different processes of health rehabilitation.[47,48] This therapy obtains positive results regarding the increase of ROM and decreases tendon stiffness, when the fascicle length and the corresponding penetration angle are evaluated.[48] Therefore, it is recommended for flexibility gain and response time with acute effect during different treatments.[47]

The PNF includes the SS and isometric contractions in an acyclic pattern for the purpose of increasing ROM. One technique involves a contract-and-relax (CR) process that includes an SS phase followed by an intense isometric contraction of the lengthened muscle, with further lengthening of the target muscle after its contraction. The other technique is the contrac-and-relax agonist-contraction (CRAC) technique . After the CR process, there is an additional contraction of the agonist muscle, that is, against the muscle group that is being stretched during the stretchingprocess, before the additional stretching of the target muscle.[49]

The dose response relationship using PNF stretching has become difficult to analyze, probably due to the limited studies on its use and factors related to the time it takes to perform the technique, which is set at an average of 5 - 50 s. Similarly, the identification of an average normally repeated CR routine of 2-5 times and an SS phase of 2.5 ± 2.9 min.[34,50,51] On the effect of power and speed using PNF stretching, scholars evidenced a reduction in jump height of (-5.1%).[16] The PNF method using the CRAC technique showed 89% to 110% higher electromyograph (EMG) activity in the ischitibial group and suggests greater muscle fatigue compared to the CR PNF method, predicting a greater exhaustive process resulting in a lower vertival jump.[50]

Results showed that the effects on performance changes induced by passive stretching (PS) or PNF were (-3.7%) and (-4.4%) respectively, considered small to moderate, immediately after the stretching tests performed.[30] It also describes, as a determining factor of these outcomes, the reduction of muscle activation after both PS and PNF exercises, showing improvements in ROM in all tests, especially when PNF combined with aerobic exercises.

However, surface electromyography verified the flexibility of the muscles of the ischiotibial group only with the use of PNF with relevant changes in jump power immediately after the intervention.[52] PNF showed a significant increase in CVJ and in effective jump height, with statistical significance $p \leq 0.05$. The decrease in activation of the semitendinosus and biceps femoris muscles was evidenced by surface electromyography.[52]

Tense hamstrings impair the jumping motion and can cause injuries to athletes who use jumping frequently. PS was the most widely used technique to mitigate these problems[52]. However, PNF may be a more effective alternative in improving tension in the ischiotibial muscle group.[53] About the increase of the average amplitude in the dorsiflexion movement, the results showed 31.1 ± 7.2 ° to 33.1 ± 7.2 ° ($P = 0.02$), the tendon stiffness decreased significantly in both active (from 21.1 ± 8.0 to 18.1 ± 5.5 N / mm) and in passive (from 12.1 ± 4.9 to 9.6 ± 3.2 N / mm) and the penetration angle increased from 18.5 ± 1.8 ° to 19.5 ± 2.1 ° ($P = 0.01$) in the neutral ankle position (90°).[48]

An impact study using PNF stretching + BS, affected performance on the VJ in a group of high flexibility participants.[14] With PNF + SS, the authors identified a decrease in VJ in groups of the sample that had high flexibility ($p \leq 0.05$). When both PNF + SS or PNF + BS techniques were developed in isolation in events that relied on burst strength as part of the warm-up step, it did not reveal significant results ($p>0.01$).[14]

Studies have become divergent on the use of PNF in acute maximal performance, demonstrating reduced values with results that conflict with outcomes of improvement or not affecting VJ performance.[50,54,55] Recent study suggests incorporating BS during competition training warm-ups for the purpose of increasing energy production.[14]

Stretches performed before sports activities as injury prevention or performance enhancement have controversial results, especially in the balance score that usually shows reduced indexes after the stretching intervention. However, stretching with PNF of the ischiotibial muscles in combination with other techniques, especially with warm-ups, has over the years shown improvements in muscle group flexibility and postural stability in athletes.[30,53,56]

The scientific findings pointed out the impact on motor unit (MU) recruitment and its stimulation frequency that favors the relationships between neural factors and the effects on muscle strength performance during contraction.[57-59]

The passive elastic properties of motoneurons have aspects related to membrane capacitance, membrane resistance, and axoplasm, which are in the order of recruitment of MU.[60] Scholars have verified the benefits of stretching in restoring the length and number of serial sarcomeres, which comes to favor hyperplasia and hypertrophy of muscle fibers.[61] However, there are propositions that the strength of a muscle may become less with increasing muscle compliance, which in turn would alter the length-tension relationship and subsequent decrease in strength due to the force-velocity relationship.[62] Similarly, the possibility that muscle compliance develops a lower stiffness of the musculotendinous unit and in the ability to recruit motor units.[62] Another factor that disfavored the acquisition of muscle strength from stretching refers to neural factors that would modify reflex response strategies and motor control.[62] The findings in research provide support for the hypothesis that SS alters the angle-torque relationship and/or sarcomere shortening velocity. Muscle tension is related to the sarcomere length, where the force generated by muscle contraction depends on the amount of cross-bridges between the actin and myosin filaments inside the sarcomeres.[63]

The time factor and/or the prolonged duration of stretching can lead to modifications in the conduct of the biological tissue, in particular, the aspects related to the musculotendinous units with possible plastic deformations and alterations, both in the force-velocity curve and in the difficulty of proprioceptive feedback. Therefore, there are negative relationships between SS and muscle power immediately after stretching is performed. While some scholars have indicated a 10 min interval to avoid significant deleterious effects, other authors have investigated stretching time of 3 to 6 min duration in the sural triceps, whose data resulted in a drop in VJ performance.[64,65]

Although a negative conception for strength and muscle power acquisition persists when stretching is performed in a more prolonged time, with PNF in a period of 10 minutes post-stretching warm-up, which may persist for up to 30 minutes, the balance and motor response indexes showed no impairment in the athlete's performance.[66] Another relevant issue is the ROM, which suffers interference from the muscle stretching time with the use of a long protocol, with an increase of 5.9% ± 0.7%, while the short warm-up protocol, the ROM showed no changes.[67]

CONCLUSION

The impact on MU recruitment and its frequency of stimulations favors neural factors and muscle strength performance during contraction. The acquisition of power in the VJ from stretching requires contemporary studies with detailed investigations of the neural factors that modify reflex responses and motor control, considering biological characteristics and plastic deformations.

The present study suggests using SS before DS in short periods of 20 seconds and no more than 60 seconds in pre-activity to VJ. In short stretches the ROM became increased in both the knee and hip, and the ischiotibial muscles, when in tension, are unfavorable in sports that frequently use the VJ. Therefore, PNF with the use of the technique that involves a process of contracting and relaxing must be investigated in an isolated and specific way preconizing the antagonist group. Thus, decreasing antagonist strength may be favorable for height gain, although contemporary studies are needed to minimize predictors of reduced stability and/or muscle control.

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