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.
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 established by 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.8,14,16 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 exercises, Muscle strength, Physical 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. Therefore, 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, Oxford, UK (www.cebm.net), which is similar to the pyramid guidelines of Murad et al. In the first collection step, the EndNote X9.1 reference manager was used.

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 VJ would 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. 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).” 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 5.5.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. 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
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. 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. However, after a certain duration of stretching resistance at the same ROM, the consequence points to a reduction in force.

Different findings occurring between the years 2000 and 2021 pointed to decreased jumping performance. 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. 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.

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. 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%.

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. Stretching time assumes to be a fundamental factor indicating small improvements in the VJ when its development was of short duration.

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. 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.

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%). 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.

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.

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. 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. Such dynamics tend to increase afferent impulses from the spindle reflex and neurons may subsequently affect performance.

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

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

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

<table>
<thead>
<tr>
<th>Author/Year/Country</th>
<th>Number of participants in the sample/ Strategies used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hespanhol et al.13</td>
<td>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.</td>
</tr>
<tr>
<td>Gómez-Alvarez et al.3</td>
<td>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, HZ, 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.</td>
</tr>
<tr>
<td>Konrad et al.7</td>
<td>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 CMVJ 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 VICOM® cameras.</td>
</tr>
<tr>
<td>Konrad et al.7</td>
<td>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 a 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 PERPLEX method.</td>
</tr>
<tr>
<td>Kirmizigil, Ozcaldiran and Colakoglu14</td>
<td>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 over 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 treatement protocols.</td>
</tr>
<tr>
<td>Bradley, Olsen and Portas16</td>
<td>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 and dynamic jump and post-stretching at 5 s, 15, 30, 45 and 60 minutes.</td>
</tr>
</tbody>
</table>

Abbreviations: BS - Ballistic Stretching; DS - Dynamic Stretching; SS - Static Stretching; ROM - Range of Motion; SS - Static Stretching with Jump; CMVJ - Counter Movement Vertical Jump; FI - Fatigue Index; PERFLEX - Perceived Effort Scale in Flexibility; AM - Average Power; PP - Peak Power; HZ - Horizontal Jump; VJ - Vertical Jump. |
rehabilitation. This therapy obtains positive results regarding the and neuromuscular ability during VJ.

Influence of different strategies with PNF and physiological

and concentric torque (7% -15%).

comes showed increased values in the hamstrings, eccentric quadriceps

techniques they characterized the potentiation process, and the out -

post-activation potentiation. In the study by Sekir et al. with similar DS

performance after DS, on the other hand, seems to be associated

the viscoelastic properties of the muscle

the possibility of a neurological impairment and a possible change in

faster rates in the same routine before activity have shown improve -

6.7% and 9.1% respectively more than activities with DS at (50 - min - 1).

Studies on a combination of dynamic movements with slow and

Stretches performed before sports activities as injury prevention or

PNF was started as a treatment method in the late 1940s by physi-

PNF includes the SS and isometric contractions in an acyclic pattern for

The PNF includes the SS and isometric contractions in an acyclic

with outcomes of improvement or not affecting VJ performance. Studies have become divergent on the use of PNF in acute maximal

However, surface electromyography verified the flexibility of the muscles of the ischiobial group only with the use of PNF with relevant

Tense hamstrings impair the jumping motion and can cause injuries to athletes who use jumping frequently. PS was the most widely used

In the study by Sekir et al. with similar DS techniques they characterized the potentiation process, and the outcomes showed increased values in the hamstrings, eccentric quadiceps 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 physi-

PNF showed a significant increase in CVJ and in effective jump height, with statistical changes in jump power immediately after the intervention. PNF showed a more effective alternative in improving tension in the ischiotibial muscle group only with the use of PNF with relevant changes in jump power immediately after the intervention. PNF showed a significant increase in CVJ and in effective jump height, with statistical significance p<0.05. The decrease in activation of the semitendinosus and a biceps femoris muscles was evidenced by surface electromyography.

An impact study using PNF stretching + BS, affected performance on the VJ in a group of high flexibility participants. With PNF + SS, the authors identified a decrease in VJ in groups of the sample that had high flexibility (p < 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).

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. Recent study suggests incorporating BS during competition training warm-ups for the purpose of increasing energy production.

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 ischiobital 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. 35,35,36

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. 37-39

The passive elastic properties of motoneurones 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 ischiobital 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.

All authors declare no potential conflict of interest related to this article

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8. All authors declare no potential conflict of interest related to this article

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