

The Effects of Hamstrings' Cooling and Cryostretching on Sit and Reach Flexibility Test Performance in Healthy Young Adults

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Authors' contributions

This work was carried out in collaboration between all authors. Author PDG designed the study and tested the participants, performed the statistical analysis and wrote the first draft of the manuscript. Authors EMT and KAF managed the analyses of the study. Author EMT reviewed the manuscript in multiple stages. Author KAF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate the effect of hamstrings' cooling and short-duration Cryostretching on sit and reach flexibility test (SR) performance.

Study Design: Crossover Randomized Clinical Trial.

Place and Duration of the Study: Department of Physical Therapy, Technological Educational Institute (TEI) of Western Greece, Aigio Achaïas, Greece, 3 months.

Methodology: Eighteen (18) healthy male (age: 21,3±4,5 yr, weight: 79,0±12,7 Kg, body fat: 14,6±4,0%) participated in the present study. Subjects were randomly divided into 3 groups which received in a random and counterbalanced order: a) hamstrings' cooling with cold packs for 15 minutes, b) hamstrings' cooling and static stretching for 14 minutes and 1 minute (30'' for each extremity), respectively and c) passive rest (control status) for 15 minutes, on three visits made. Sit and Reach (SR) test, was applied before and after each intervention to assess the hamstrings' flexibility.

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Results: Baseline Sit-and Reach results (SR 1) did not differ significantly between all 3 conditions (Cooling vs Control: 13,6±5,8 cm vs 13,8±7,1 cm $P = 0,817$; Cryostretching vs Control: 13,4±6,3 cm vs 13,8±7,1 cm $P=0,620$; Cooling vs Cryostretching: 13,6±5,8 vs 13,4±6,3 cm $P=0,817$). A significant improvement of hamstrings' flexibility in SR2, was observed after hamstrings' cooling intervention compared to corresponding values of Control (14,5±6,1 cm vs 13,2±7,0 cm $P=0,026$) and after cryostretching intervention compared to corresponding values of Control (14,9 ± 6,6 cm vs 13,2±7,0 cm, $P=0,011$). Flexibility values of hamstrings' cooling alone compared with those after hamstrings' cooling associated with a short bout of cryostretching (in SR 2), did not differ significantly (14,5±6,1 cm vs 14,9±6,6 cm, $P= 0,502$).

Conclusion: Hamstrings' cooling and cryostretching can improve performance in SR test and thus can be used as alternative methods for increasing the hamstrings' flexibility in short term.

Keywords: Hamstrings; flexibility; Cryostretching; sit and reach test.

1. INTRODUCTION

Musculoskeletal and sports injuries occur as a result of multiple factors, both extrinsic and intrinsic. Extrinsic factors include amongst others the direct contact with an opponent, inadequate warm-up, and shoes, playing on artificial turf and training mistakes and overloading. Primary sources of intrinsic etiology are anatomical and anthropometric asymmetries, age, previous injury and deficits in neuromuscular control, strength and flexibility [1-7]. More specifically research findings regarding asymmetries in muscle flexibility and previous injuries are more definite regarding their connection to the occurrence of muscle injuries in the lower limbs of the professional athletes [8-10].

Flexibility is a biomechanical property of the body tissues that determines the range of motion achievable without injury at a joint or group of joints [11]. Athletes must have an adequate joint range of motion (ROM) safely and optimally to perform the particular skill of his sport. For example, functional flexibility for a soccer player would require greater lengthening of the hamstring than that needed for a cyclist. In that direction athletes, trainers and sports physiotherapists use sports-specific stretching at their daily training or rehabilitative regime to both prevent injury and enhance performance.

Studies on flexibility [12-16] evaluated the extent and duration of the effect of stretching on specific joints and muscles group (especially hamstrings'), as well as the effectiveness of different techniques of stretching. From their findings, it is evident that stretching application of 15-30s is more efficient than shorter duration stretches [12] and as useful as applications of longer duration [13,14]. Static stretching techniques have been found to increase flexibility

with this adaptation been attributed mainly to sensory modification, rather than to an increased muscle tissue length per se [15,16].

Alternative methods of stretching, including dynamic stretching and proprioceptive neuromuscular facilitation (PNF) techniques, have been evaluated for their effects on flexibility [17,18].

In a vast majority of the studies, all of stretching techniques were demonstrated to increase joint flexibility. Nevertheless, the comparative evaluation of the effect of different stretching techniques has led to contradictory results. For example, while there is enough evidence [19-22] supporting the effectiveness of PNF stretching over other stretching techniques in improving flexibility, this has not been demonstrated consistently [23-25].

More recently, several novel stretching techniques have been developed including the use of physical agents (hot or cold) before or simultaneously with the application of stretches. Applying heat packs before stretching has been widely studied and appears to contribute to a further increase in flexibility compared to stretching applications alone [26-35]. Also, local and the whole body cooling/cryotherapy applications have applied and tested in several studies [28,36-37] given that various cold applications can decrease superficial [38-43] and intramuscular temperatures [38,44-47] as well as muscle pain and spasm through a temporary inhibition of muscle spindles of the application area [7,48-49].

In this direction, it has been reported that hamstrings' stretching with simultaneous use of ice, appears to be more efficient than either stretching alone or stretching with heat [28].

Furthermore, decreased stretch sensation after cold packs application without passive stretching improved the passive and active ROM of internal rotation and horizontal adduction in subjects with posterior shoulder tightness, similar to stretch use [36]. Reinforcing previous results, Halkovich et al. [37] showed that vapocoolant application with Fluori-Methane® spray and passive static stretch did significantly increase the range of passive hip flexion over that of the control group, which received only passive static stretch.

Contrary to previous findings, other studies showed no association between cold-assisted stretching and increased flexibility [27,50]. Cornelius et al. [50] studying the effects of modified Proprioceptive Neuromuscular Facilitation (PNF) flexibility techniques on hip flexion in college males to determine if local cold application enhances the effectiveness of these techniques reported that cold use does not influence the effectiveness of selected stretching techniques. Furthermore, Taylor et al. [27], showed that the use of superficial cooling does not increase the efficacy of static stretch on improving hamstrings' flexibility.

Furthermore, there are numerous flexibility testing procedures [51] that have been advocated as a means of indirectly measuring hamstring length. A popular and widely used method especially in Functional Testing Procedures is the sit-and-reach test (SR). This functional test, although, it does not isolate the hamstrings' and in fact, it depicts the overall posterior extensibility of the athletes' body, presenting high measurement validity and reliability [52, 53].

In summary, there is no clear evidence about whether a cold application with or without static stretching is an effective method to increase muscle flexibility. To our knowledge, there is no published research examining the effect of hamstrings' cooling and Cryostretching, on sit and reach flexibility (SR) test performance. The purpose of the present study was a) to examine if hamstring cooling increase the SR performance and b) to evaluate if the combined application of hamstring cooling with static stretching would enhance this effect.

2. METHODOLOGY

2.1 Participants

A sample of eighteen healthy male volunteers (Mean \pm SD: age 21,3 \pm 4,5 yr, height 179,3 \pm 6,7

cm, body mass 79,0 \pm 12,7 kg, BMI 24,5 \pm 3,1, body fat 14,6 \pm 4,0 %, right thigh circumference 54,9 \pm 5,3 cm, left thigh circumference 54,8 \pm 5,4 cm) agreed to participate in the study. Inclusion criteria required physically active participants with no history of musculoskeletal injury at the lower extremities for at least six months before the trial. All participants were initially briefed on experimental procedure and signed a consent form of voluntary participation. All measurements performed in the Human Assessment and Rehabilitation Laboratory, Department of Physical Therapy, Technological Educational Institute (TEI) of Western Greece.

2.2 Experimental Design

The experimental design of this study was a Crossover Randomized Clinical Trial approved by the ethics committee of the Technological Educational Institute of Western Greece (School of Health Sciences/ 17258/29-4-2015). Each volunteer participated in three different experimental conditions on separate visits to the research lab with a seven days' interval. Participants were instructed to maintain physical activity levels they have had before the start of the research study. The three experimental conditions, namely plain Cooling (Cooling), Stretching with cryotherapy (Cryostretching) and doing only the flexibility testing (Control) were performed in a random and counterbalanced order, as shown in Table 1. The laboratory was set to maintain thermoneutral atmospheric conditions (Temperature: 19-22°C, Relative Humidity: 30-40% rh) which were monitored continuously during interventions and data collection (Beurer, HM 16, Germany).

2.3 Procedures

2.3.1 Evaluation protocol

Participants initially performed two sets of eight consecutive repetitions of SR test, as familiarization/warm-up procedure, with an average break of three minutes (without having their performance recorded). Three minutes after the end of the second set of familiarization/warm-up procedure, participants performed three attempts in the SR test (SR 1) and the max value (Maxflex) of them was collected for the analysis (Fig. 1). For the SR test, the participant sat with their feet against the testing box and with their knees fully extended. In order, to ensure the full extension of the knees in the duration of the test, the examiner pushed down with his hand both

Table 1. Randomization of the testing conditions for the participants (n=18)

Sample	1 st Condition	2 nd Condition	3 rd Condition
n=18	n=3	Control	Cryostretching
	n=3	Control	Cooling
	n=3	Cooling	Control
	n=3	Cooling	Cryostretching
	n=3	Cryostretching	Control
	n=3	Cryostretching	Cooling

knees as shown in Fig. 1. Afterward, the participant placed one hand over the other and slowly reached forward as far as they could by sliding their fingers along the measuring board.



Fig. 1. Flexibility assessment of the participants with sit and reach (SR) test

2.3.2 Cooling condition

The second part of the trial included the cooling procedure of the hamstrings' (Fig. 2). For this procedure, the participant was lying prone and cold packs with dimensions 11"x14" in (Clacier Pack S03060, Whitewall, USA) were placed on hamstrings' of both thighs. The cold packs, before application, were cooled up to 8 hours using a freezer (Clacier Freeze, Whitewall manufacturing, USA) with operating temperature at -20°C. For skin protection purposes, a wet towel (water temperature: 16-18°C) was placed between the skin and the cold pack. The cold packs were fixed using retaining elastic bands with constant compression force covering the somatic area from just above (2 cm) the popliteal region of each knee to the gluteal fold approximately (origin of hamstrings'). The cold packs were placed by the same investigator at all times (PG) to ensure reliability. Upon completion of the cold-packs placement, started next recording of the application time with a precision digital stopwatch (Casio, LW-200, CHINA). The hamstrings' cooling method lasted 15 minutes, in total and afterward the SR test (SR2) was performed as described previously (SR 1).

2.3.3 Cryostretching condition

The participants in Cryostretching condition participated in the same set of procedures with Cool condition, with the difference that after the 14 min of hamstrings' cooling process a passive static hamstring stretching (30 seconds on each leg) was applied by the physiotherapist (PG) without removing of the cold packs.

The application of static stretching was performed with the participants lying supine and with both knees in full extension and ankles in a neutral position. Upon implementation of static stretching on each foot, the researcher placed his distal arm on the posteriorly to the heel, lifting the lower limb, while the knee remained fully extended and the ankle free. The proximal hand maintained knee extension by applying pressure to the anterior surface of the thigh. The stretching progressively reached the maximum available ROM, with the participant starting to experience pain and lasted for 30 seconds. During the application of stretching, two immobilization belts were used to stabilize the pelvis and opposite leg (Fig. 3). Immediately afterward, the same procedure was repeated for the contralateral leg. Upon completion of static stretching in both legs, participants had completed a total period of 15 minutes' starting from the application of cold packs and terminated by removing them as in the Cooling condition, respectively. The participants afterward performed the SR test 2 as described previously in the Cooling condition.

2.3.4 Control condition

The participants in Control condition performed the same set of procedures in the same manner, just like during the Cooling and Cryostretching with the only difference that were making passive idle in prone position above the 15 minutes' time period, instead of having intervention of 15 minutes cooling period for the hamstrings' (Cooling) or cooling application in combination with static stretching of hamstrings' during the last minute (Cryostretching).



Fig. 2. The three consecutively stages until completion the cooling application



Fig. 3. The initial and final position of stretching procedure in Cryostretching condition

2.4 Statistical Analysis

The data of the study were tested and confirmed for their normal distribution with the use of Shapiro-Wilk test (Control SR 1: $P = 0,190$; Cooling SR 1: $P = 0,222$; Cryostretching SR 1 $P = 0,073$; Control SR 2: $P = 0,182$; Cooling SR 2: $P = 0,073$; Cryostretching SR 2 $P = 0,332$). Pre- and post-intervention measurements were compared between groups using analysis of variance (ANOVA) with Bonferroni post-hoc analysis. The analysis was performed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p < 0,05$.

3. RESULTS AND DISCUSSION

The physical, age and selected anthropometric characteristics of the participants are given in Table 2.

Sit and Reach flexibility test results in Maxflex procedure (SR 1) which was performed before the intervention in all three conditions (Control, Cooling and Cryostretching) were presented in

Fig. 4. There were no statistically significant differences between the three conditions for the parameter of Maxflex distances (Cooling vs Control: $13,6 \pm 5,8$ cm vs $13,8 \pm 7,1$ cm $P = 0,817$; Cryostretching vs Control: $13,4 \pm 6,3$ cm vs $13,8 \pm 7,1$ cm $P = 0,620$; Cooling vs Cryostretching: $13,6 \pm 5,8$ vs $13,4 \pm 6,3$ cm $P = 0,817$).

The results of Maxflex in sit and reach flexibility test 2 (SR 2) which performed 1 minute after the end of each intervention (Cooling and Cryostretching) or without intervention in Controls are presented in Fig. 5. A significant increase in Maxflex in both Cooling ($14,5 \pm 6,1$ cm, $P = 0,026$, Observed Power: 0,631) and Cryostretching ($14,9 \pm 6,6$ cm, $P = 0,011$, Observed Power: 0,772) was observed in SR 2 condition, in comparison with the value in Control ($13,2 \pm 7,0$ cm) condition. Flexibility values of Cooling and Cryostretching condition in SR 2, did not differ significantly ($P = 0,502$, Observed Power: 0,099).

This is the first trial assessing the short-term flexibility adaptations after hamstrings' cooling

with cold packs alone or associated with a short bout of stretching, using the global extensor flexibility assessment with the classical Sit-and-Reach test (SR). SR test is a clinical tool used by many clinicians for flexibility assessment, while it appears to be affected more from the hamstrings' than the lumbar extensors flexibility, possessing a moderate criterion-related validity for estimating hamstrings' flexibility [54].

The results of the present study showed that cold pack application over hamstring enhances short-term flexibility scores on SR test. This adaptation can be explained by the fact that the application of cold packs has been shown to reduce a) nerve conduction velocity, b) superficial and intramuscular temperature [38-41,44-46], and c) muscle spasm through temporary inhibition of muscle spindles activity [7,48-49,55].

The aforementioned neuromuscular adaptations after hamstrings' cooling in our study might have

caused decreased stretch sensation and a localized hypoalgesic effect, resulting in our participant's better performance in the Sit and Reach Test [49]. Furthermore, these findings can be attributed to sensory adaptations after cryotherapy as it has been reported that increased pressure pain thresholds after cooling applications can improve a restricted ROM [16,36]. In support of previous theory Anaya Terroba et al. [56] investigating the effects of ice massaging on pressure pain thresholds over the knee extensors reported that ice massage might result in a significant local hypoalgesic effect. So, it seems logical to suggest that ice application eased stretch discomfort felt from our participants at the end range of the stretch, allowing more intense stretching.

The application of 30 sec static stretching, in combination with cold pack application (Cryostretching), did not result in greater improvement ($p=0,502$) on hamstring flexibility

Table 2. The anthropometric traits (Mean ± SD) of the participants (n=18) who participated in the experimental procedure

Age (yr)	Weight (kg)	Height (cm)	BMI (Kg/m ²)	Body fat (%)	RTC20 (cm)	LTC20 (cm)
21,3 ± 4,5	79,0 ± 12,7	179,3 ± 6,7	24,5 ± 3,1	14,6 ± 4,0	54,9±5,3	54,8±5,4

BMI: Body mass index; RTC20: Right thigh circumference measured 20 cm up to patella upper pole; LTC20: Left thigh circumference measured 20 cm up to patella upper pole

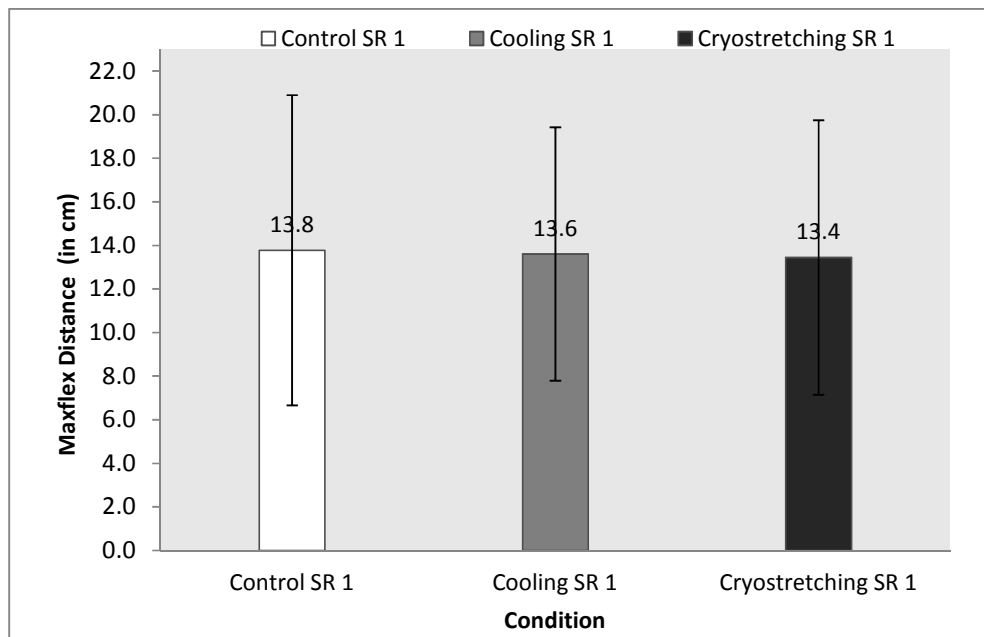


Fig. 4. Means scores (±SD) of Maxflex distances (cm) in sit and reach flexibility test 1 (SR 1)
 There were no statistically significant differences ($P>0,05$) between the three conditions in SR 1

compared with cooling condition alone. This finding is in agreement with those reported by Park et al. [36] in a study examining the immediate effects of local cryotherapy (LC) and passive cross-body stretch on the flexibility of the posterior shoulder muscle in individuals with posterior shoulder tightness. Their results showed that the application of cryotherapy (without passive stretching) led to a significant improvement in the passive and active ROM of internal rotation and horizontal adduction in subjects with posterior shoulder tightness, similar to cross-body stretch. These cryotherapy-induced gains in shoulder flexibility were also attributed to the reduction of the uncomfortable stretch sensation, and to the increase in pressure pain threshold (PPT) of shoulder muscles observed after cryotherapy applications. At the other hand, Brodowicz et al. [28] reported that stretching with ice application led to a better short-term improvement in hamstring flexibility than stretching with heat or stretching alone. This differentiation, however, may be explained by methodological differences of the investigations. Specifically, Brodowicz et al. [28] performed a 20-minute stretching routine with cold packs secured to the posterior thigh of each leg while in our study the corresponding stretching application lasted only 30''.

This study has several methodological limitations. The main limitation of the survey was that didn't evaluate the effects of stretching. That was made because the short-term stretching adaptations in regards joint ROM improvement are clear and well established in the literature. More precisely, flexibility gains after passive stretching have been connected with an increase in the length of stretched muscle and the number of sarcomeres in series and to elongation of connective tissue [27,57,58]. Furthermore, the present study intended to concentrate in the evaluation of the short-term flexibility adaptations solely after cold packs application.

Other limitations include methodological issues and deficits such as selection of the assessment technique-tool and participants. The Sit and Reach test that was used as an evaluation tool in the study has several disadvantages as it examines not only the flexibility of the hamstrings' but also this of the back muscles. Furthermore, another limitation of the traditional sit and reach procedure is that people with long arms and/or short legs would get better results than those with short arms and/or long legs. Nevertheless, Mayorga-Vega et al. [54] in their meta-analysis regarding criterion-related validity of sit and reach test for estimating hamstrings'

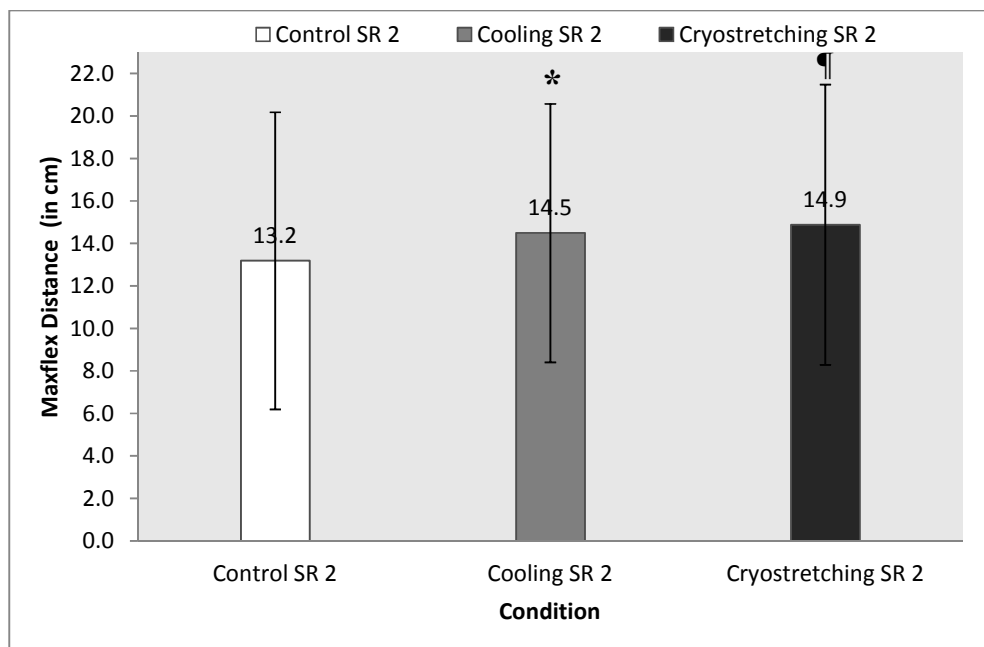


Fig. 5. Means scores (\pm SD) of Maxflex distances (cm) in sit and reach flexibility test 2 (SR 2)
 The symbol (*) indicates $p < 0,05$ between Cooling and Control. The symbol (†) indicates $p < 0,05$ between Cryostretching and Control. There were no statistically significant differences between Cooling and Cryostretching ($p = 0,502$)

and lumbar extensibility reported sit-and-reach tests seem to be a useful test alternative to assess hamstring flexibility, but not to evaluate lumbar flexibility. Furthermore, the initial selection of participants in the experimental procedure is not carried by some method of randomization, and thus, the sample consists a convenience sample. However, the execution order of the experimental conditions performed in a random and counterbalanced order. Our findings cannot be generalized to other populations because all subjects in our study were young. Furthermore, we investigated the immediate effects of LC and stretching on joint ROM, and further long-term investigations are needed.

Further studies are required in order to examine the effectiveness of the combined application of different cooling methods (method of cooling, duration of use) in conjunction with the implementation of various stretching applications (types of stretching-duration) in flexibility improvement to be clarified. Another interesting element that deserved to be investigated would be to evaluate the effect of cryotherapy on different tissues of the muscle. For example, no data exists on the effectiveness of hamstrings' tendons' cooling versus hamstrings' muscles bellies cooling in short-term flexibility improvement.

4. CONCLUSIONS

The application of localized cryotherapy with cold packs with or without static stretching probably increase hamstrings' flexibility in young participants as measured by sit and reach test. Based on the results of this study we recommend clinicians to use both specific applications (Cooling and Cryostretching) as alternatives but also as effective methods for increasing the hamstrings' flexibility in the short term.

CONSENT

All authors declare that written informed consent was obtained from the patient (or other approved parties) for publication of this paper and accompanying images.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the ethics committee of the Technological Educational Institute of Western Greece (School of Health

Sciences/ 17258/29-4-2015) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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