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Original paper

Negative effect of static stretching restored when combined with a sport specific warm-up component

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Abstract

There is substantial evidence that static stretching may inhibit performance in strength and power activities. However, most of this research has involved stretching routines dissimilar to those practiced by athletes. The purpose of this study was to evaluate whether the decline in performance normally associated with static stretching pervades when the static stretching is conducted prior to a sport specific warm-up. Thirteen netball players completed two experimental warm-up conditions. Day 1 warm-up involved a submaximal run followed by 15 min of static stretching and a netball specific skill warm-up. Day 2 followed the same design; however, the static stretching was replaced with a 15 min dynamic warm-up routine to allow for a direct comparison between the static stretching and dynamic warm-up effects. Participants performed a countermovement vertical jump and 20 m sprint after the first warm-up intervention (static or dynamic) and also after the netball specific skill warm-up. The static stretching condition resulted in significantly worse performance than the dynamic warm-up in vertical jump height (−4.2%, 0.40 ES) and 20 m sprint time (1.4%, 0.34 ES) ($p < 0.05$). However, no significant differences in either performance variable were evident when the skill-based warm-up was preceded by static stretching or a dynamic warm-up routine. This suggests that the practice of a subsequent high-intensity skill based warm-up restored the differences between the two warm-up interventions. Hence, if static stretching is to be included in the warm-up period, it is recommended that a period of high-intensity sport-specific skills based activity is included prior to the on-court/field performance.

Keywords: Stretching; Dynamic warm-up; Power; Sprinting; Netball

1. Introduction

The purpose of the pre-competition warm-up is to prepare athletes for the demands of the competition. A well-designed warm-up can assist the athlete in mentally focusing on the upcoming task and to bring about various physiological changes to optimise performance.[1] A pre-game warm-up for team sports typically includes a period of sub maximal running, static stretching of the major muscle groups and sport specific movements incorporating various range of motion (ROM) exercises with skill-based drills executed at, or just below game intensity.[2]

Low to moderate intensity aerobic activity is an important element of the warm-up as it increases muscle temperature, which is directly responsible for a number of mechanisms important for short term performance, including range of movement about the joints, increased rate of nerve impulses, and an altered force–velocity relationship.[3] In contrast, the static stretching component, which is routinely practiced in team sports, has little scientific basis to support a beneficial effect on sports performance. In fact, substantial evidence exists that static stretching may acutely inhibit performance in strength and power activities, with previous research reporting negative effects on maximal isometric force,[4,5] one repetition maximum strength[6] and explosive performance as measured by a countermovement vertical jump,[7,8] drop-jumps[7–9] and 20 m sprint performance.[10,11] Acute bouts of stretching have also been shown to impair balance, reaction time and movement time.[12] The lack of evidence in favour of static stretching during a warm-up has led some authors to

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recommend the exclusion of this component from the warm-up for strength and power activities.[13,14]

Awareness of the substantial evidence suggesting acute impairment of strength and power following static stretching has led to some coaches combining and/or replacing static stretching with dynamic warm-up routines. McMillian et al.[15] found that a dynamic stretching routine produced higher (2.8%, ES 0.24) scores for a five-step jump than when static stretching was utilised. Similarly, dynamic stretching produced faster (2.8%, ES 0.51) 20 m sprint performance[10] and greater (11.56%, ES 2.23) leg extension power[16] than static stretching. Such evidence suggests that dynamic warm-up routines have a greater beneficial effect on powerful-based performances than static stretching routines. However, an important component of the warm-up sequence that has generally been overlooked in the literature to date is the sport specific warm-up activities that are commonly included in many team sport warm-up routines. Only Young and Behm[7] have investigated the effect of specific rehearsal of the test activity subsequent to a bout of static stretching. They examined the influence of practice jumps in combination with a 4 min submaximal run and static stretching and reported better performance for a variety of jump variables when the subjects were given opportunity to perform practice jumps. The authors suggested that rehearsal of the skill to be performed may have had an effect of "opening up" the specific neural pathways, facilitating motor unit activation, and therefore assisting to improve explosive performance.[7] In addition to these findings, Young and Behm[7] also reported that a run + stretch condition produced very similar mean results to their control condition, leading them to believe that perhaps the run + stretch condition might be made up of a positive influence (run) and a negative influence (stretch), which counteracted each other to produce results similar to the control condition. While their study design did not include an additional warm-up condition to examine the effect of a warm-up consisting of only two positive influences, for example the run + skill rehearsal, they hypothesised such a warm-up routine may be the most beneficial combination of activities.

Therefore, the purpose of the current research was to replicate current warm-up practice in netball to evaluate differences in speed and leg extensor power after static stretching and dynamic warm-up routines. A further objective was to determine if differences in performance remained after a period of moderate to high intensity skill rehearsal. That is, we were interested in investigating if the hypothesised negative effect of stretching would remain after a sport specific warm-up sequence.

2. Methods

Thirteen players from the Australian Institute of Sport (AIS) Netball program (mean ± standard deviations (S.D.) age, height, and mass of 19.6 ± 0.8 years, 184.8 ± 6.3 cm and 75.2 ± 10.3 kg, respectively) participated in this study. All players received a clear explanation of the study, including the risks and benefits of participation. Testing was in accordance with and approved by institutional ethics, and written consent for testing was obtained in the player's scholarship holder's agreement.

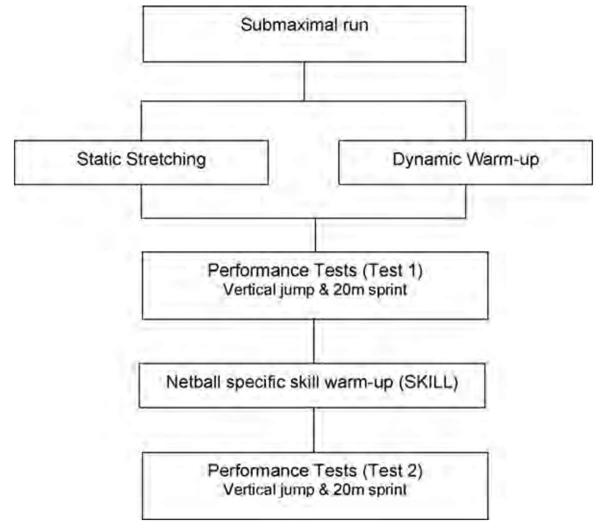

Fig. 1. Schematic representation of the study design and testing procedures used.

Although the participants were highly familiar with the testing battery (minimum of 12 previous experiences) and had extensive experiences with the warm-up types, two familiarisation sessions were conducted to outline the protocols of the experiment. The experimental design consisted of two test sessions scheduled a week apart, allowing testing to be conducted at a similar time of day with similar activity prior to testing, using a within-subjects design. In each session players completed a submaximal run followed by either a static stretching or a dynamic warm-up routine, and after 2–3 min rest they completed the first set of performance tests (20 m sprint and vertical jump test; Test 1). They then participated in a netball specific skill warm-up (SKILL) and were once again tested for sprint time and vertical jump height (Test 2; see Fig. 1). Due to certain restrictions imposed by the training environment, the order of the experimental conditions could not be randomised to control for order effect, but the extensive experience of the subjects with the conditions and the procedures was believed to have attenuated possible order effects.

On each testing occasion the first warm-up intervention (static or dynamic) was preceded by a sub-maximal jog equivalent to 12 laps of a netball court (total distance of 300 m). The static stretching warm-up consisted of nine static stretching exercises for the lower body. Briefly, the stretches included; (1) standing calf stretch, (2) kneeling Achilles tendon stretch, (3) seated hamstring stretch, (4) seated gluteus maximus stretch leaning forward with one foot on the leg, (5) standing quadriceps stretch, (6) lying lower back stretch, (7) seated groin stretch, (8) kneeling hip flexor stretch and (9) quadratus lumborum stretch. All stretches were held for 30 s each, with

Table 1
Dynamic warm-up routine

1. High knees × 3 (over 20 m)
2. Butt flicks × 3 (over 20 m)
3. Carioca × 2 each side (over 20 m)
4. Dynamic hamstring swings × 10 each side
5. Dynamic groin swings × 10 each side
6. Arm swings—forwards/backwards × 10 each direction
7. Faster high knees (shorter stride) over 10 m × 4
8. Swerving × 2 over 30 m at 70%
9. Side stepping over 30 m × 2 at 80%
10. Spiderman walks over 20 m
11. Sideways low squat walks × 10 steps each direction
12. Upper body rotations × 10 each direction
13. Vertical jump × 5—building in intensity
14. Run through over 20 m: 70% × 2; 80% × 2; 90% × 1 (over 10 m)
15. Countermovement jump then 5 m sprint at 90% × 2; 95% × 1 (10 m)
16. Sprint for 5 m then countermovement jump × 2

stretches 1–6 repeated twice for each limb and stretches 7–9 only repeated once on each limb. Subjects provided their own resistance for all stretches with the instructions to stretch the muscle to the point of minor discomfort. All stretches were ones that players used in their regular warm-up routines. The entire static stretching protocol took approximately 15 min to complete.

The exercises included in the dynamic warm-up intervention are described in Table 1. Briefly the exercises were whole body, closed-skill movements emphasising range of motion and gradually progressing in intensity. Each exercise repetition was followed by 10–15 s rest. The dynamic warm-up also lasted approximately 15 min. On both days, subsequent to the static and dynamic warm-up, players also completed a sport specific skill warm-up (SKILL) that was designed to replicate their usual pre-game preparation. This included an additional 15 min of various netball specific, open-skilled ball drills that consisted of various combinations of short sprints (ranging from 5 to 10 m), shuffling, accelerations (i.e. 3–4 steps), changes of direction and various jumps (single- and double-legged). The drills in this component of the warm-up were generally completed just below or at game intensity.

At the completion of each warm-up protocol, players were given 2–3 min rest before the 20 m sprint and countermovement vertical jump test (the order of testing was retained for each session, so that the rest time for each subject was consistent between testing occasions). Players were given two attempts for the 20 m sprint and vertical jump with their best result used for analysis. A minimum of 60 s recovery separated trials. Sprint time was measured using electronic dual-beam timing gates (Swift Performance, Lismore, Australia). To assess jumping performance the participants performed a maximal effort bilateral countermovement jump using a vaned jump and reach apparatus (Yardstick, Swift Performance Technologies, Lismore, Australia), where they were instructed to stand with feet approximately shoulder width apart, perform a countermovement to a self-selected depth and jump for maximal height. The test–retest reliability of the 20 m sprint and the vertical jump assessments for this group of athletes has previously been established (Typical Error = 1.95 cm and 0.03 s; CV% = 1.2 and 1.4; for the vertical jump and 20 m sprint, respectively).

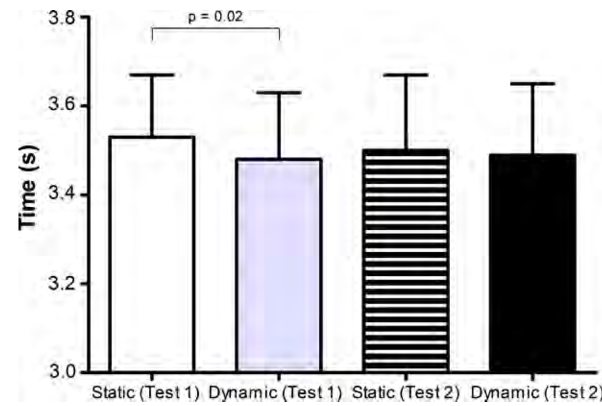

Fig. 2. Mean 20 m sprint time following each warm-up condition.

Paired *t*-tests were performed to determine if there were any differences between the warm-up conditions and the performance variables (SPSS for windows, SPSS, Inc., Chicago, IL, USA). Statistical significance was accepted at the $p < 0.05$ level with data presented as mean ± S.D. In addition 95% confidence interval (CI) (defining the likely range of the true value in the population from which the sample was drawn) for mean scores were also calculated and presented where appropriate. The magnitude of difference between conditions was evaluated using Cohen's effect size (ES) calculations, with the magnitude of differences interpreted according to the criteria of Rhea,[17] where <0.25 = trivial, 2.5–0.5 = small, 0.5–1.0 = moderate, and >1.0 = large effects.

3. Results

Descriptive statistics for the performance variables in each warm-up condition are presented in Table 2. As hypothesised, the static stretching condition resulted in significantly

Table 2
Means (95% CI) for vertical jump height (VJ) and 20 m sprint performance following static stretching and dynamic stretching routines (Test 1) and after the SKILL warm-up (Test 2)

	Test 1		Test 2	
	VJ (cm)	Sprint (s)	VJ (cm)	Sprint (s)
Static	43.1 (40.1–46.0)	3.53 (3.45–3.61)	45.5 (42.5–48.6)	3.50 (3.40–3.60)
Dynamic	45.0 (42.1–47.9)	3.48 (3.39–3.57)	45.9 (42.8–48.9)	3.49 (3.39–3.59)

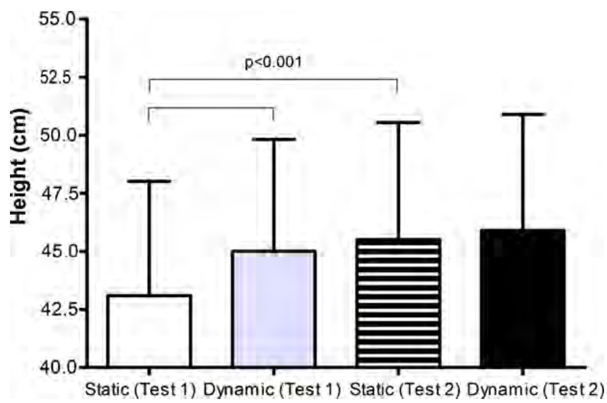

Fig. 3. Mean jump height following each warm-up condition.

worse performance than the dynamic warm-up in vertical jump height (−4.2%, 0.40 ES) and 20 m sprint time (1.4%, 0.34 ES) (Figs. 2 and 3). The VJ and sprint performance in the static stretching condition were improved after the SKILL component was performed (5.3% and 0.9%, respectively). No significant differences were observed between the dynamic warm-up on its own and the combined dynamic and SKILL warm-up (differences of 2.0% for the VJ and −0.3% for the sprint; $p > 0.05$).

When the post-SKILL performances for both conditions were compared, no significant differences existed for either performance variables, with mean vertical jump heights after static- and dynamic-Test 2 of 45.5 cm (95% CI: 42.5–48.6 cm) and 45.9 cm (95% CI: 42.8–48.9 cm), respectively (with a trivial ES of 0.21). Similarly, mean sprint performance was very similar after both warm-up conditions (95% CI: 3.40–3.60 s and 3.39–3.59 s for static and dynamic conditions, respectively; 0.06 ES).

4. Discussion

While many researchers have shown that static stretching can inhibit strength and power performance, they have tended to use stretching protocols that do not replicate current practice in preparation for dynamic sports performance, generally using stretching protocols with extensive time under tension per muscle group, or using static stretching in isolation. The purpose of this study was to determine the performance effect of static stretching that is undertaken as a component of a typical team warm-up routine, so that advice could be given to coaches regarding the value of static stretching in the normal warm-up sequence. Similar to previous findings, our results indicate that static stretching in isolation does not optimally prepare an athlete for powerful performance.[8–10,13]

The significantly poorer jump and sprint performances after the static stretching warm-up compared to the dynamic warm-up support evidence from the numerous studies that have shown better performance on tests of muscle strength and power after a dynamic warm-up routine.[10,15,18] However, it is difficult to elucidate whether the differences in performance following static stretching and the dynamic warm-up were solely due to the stretching intervention, as it is possible that muscle temperature had a confounding effect on the results. That is, it is likely that the dynamic warm-up elevated muscle temperature significantly more than the static stretching protocol, which has been shown to encourage more rapid and forceful muscle contractions.[19] While this would significantly impact the interpretation of results if our intention was to understand the mechanism for reduced performance following static stretching, this was not the purpose of this study. Our primary objective was to establish an understanding of the role of static stretching within a warm-up routine that is commonly used in practice, which as previously stated involves a combination of periods of sub maximal running, static stretching, and periods of sport specific skill-based drills executed at, or just below game intensity.[2] We therefore considered it irrelevant to look at static stretching and a dynamic warm-up in isolation as this rarely, if ever practiced in a competitive team sport environment.

When we examined the interactive effects of static stretching and moderate to high intensity sport specific warm-up, as is common occurrence in many team sports, we found that the negative influence of static stretching on performance was attenuated. That is, there were no differences in performance after the SKILL warm-up in both conditions (static and dynamic). These results suggest that if an inhibitory effect was present after static stretching, that the SKILL component of the warm-up routine was able to dissipate the negative effect. This supports the suggestion by Young and Behm[2] that practice attempts of the required tasks may offset any potential negative effects of static stretching, as the SKILL component of the warm-up routine used in this study incorporated activities with very similar neuromuscular and energetic requirements to those needed to successfully perform the performance tests. This is in contrast to findings of Stewart et al.[20] who reported slower 40 m sprint times after a dynamic, performance specific warm-up was combined with 12 min of static stretching than when the dynamic warm-up was performed without any static stretching ($p = 0.075$). These findings however, were likely influenced by the order of the warm-up components, as the sprint performance was immediately preceded by the 12 min static stretching protocol, showing that the sequencing of warm-up activities is likely to have a significant effect on the performance outcomes. This highlights that while the findings from the present study have shown that it is likely that static stretching in a warm-up may not hinder performance as has been previously suggested,[7] other considerations such as the sequencing of activities may need to be considered. Based on our findings and those of Stewart et al.,[20] we suggest that if static stretching is included in the warm-up, that it should be sequenced prior to moderate to high intensity skill based warm-up activities.

Another important consideration when prescribing warm-up activities is also the volume of the static stretching protocol. In designing the stretching/warm-up interventions in the present study we aimed to ensure that the protocols were realistic and reflective of current athletic practices. Many previous studies demonstrating a stretch-induced impairment of performance have used protocols that exceed 2 min of total time under stretch for each muscle group,[5,6,11,12,20] however in a typical warm-up total time under stress is more likely in the range of 0.5–2.0 min per muscle group.[21] This is likely an important variable to consider, as findings from Young et al.[9] indicated that impairments in drop jump performance tended to increase when the volume of stretching was increased from 1 to 4 min, supporting the notion of a volume-effect. Therefore although our findings have indicated that the inclusion of static stretching did not hinder performance when it preceded the SKILL warm-up, coaches and practitioners should be aware that an increase in the volume of stretching may have a significant impact on the performance outcomes.

5. Conclusions

Although the need for a warm-up before high intensity performance is rarely questioned, the precise protocol leading to optimum performance is not well established.[2] The most important findings from this study were that a dynamic warm-up routine is superior to static stretching when preparing for powerful performance; however, these differences can be eliminated if followed by a moderate to high intensity sport specific skill warm-up.

Practical implications

- If static stretching is included in place of, or in addition to a dynamic warm-up routine, it should be followed by a period of moderate to high intensity sport specific activity that includes some form of skill rehearsal.
- A dynamic warm-up routine is superior to static stretching when preparing for powerful performance.

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