

Research article

Effects of dynamic and static stretching within general and activity specific warm-up protocols

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Abstract

The purpose of the study was to determine the effects of static and dynamic stretching protocols within general and activity specific warm-ups. Nine male and ten female subjects were tested under four warm-up conditions including a 1) general aerobic warm-up with static stretching, 2) general aerobic warm-up with dynamic stretching, 3) general and specific warm-up with static stretching and 4) general and specific warm-up with dynamic stretching. Following all conditions, subjects were tested for movement time (kicking movement of leg over 0.5 m distance), countermovement jump height, sit and reach flexibility and 6 repetitions of 20 metre sprints. Results indicated that when a sport specific warm-up was included, there was an 0.94% improvement ($p = 0.0013$) in 20 meter sprint time with both the dynamic and static stretch groups. No such difference in sprint performance between dynamic and static stretch groups existed in the absence of the sport specific warm-up. The static stretch condition increased sit and reach range of motion (ROM) by 2.8% more ($p = 0.0083$) than the dynamic condition. These results would support the use of static stretching within an activity specific warm-up to ensure maximal ROM along with an enhancement in sprint performance.

Key words: Flexibility, sports performance, jumps, reaction time.

Introduction

The evidence for stretch-induced performance decrements (see review; Behm and Chaouachi, 2011) has led to a paradigm shift on optimal stretching routines within a warm-up. In view of the bulk of static stretch-induced impairment evidence, many athletic teams and individuals have now incorporated dynamic stretching into their warm-up. Dynamic stretching would be expected to be superior to static stretching due to the closer similarity to movements that occur during subsequent exercises (Torres et al., 2008). However the evidence is not unanimous. Studies implementing dynamic stretching have reported both facilitation of power (Manoel et al., 2008), sprint (Fletcher and Anness, 2007; Little and Williams, 2006) and jump performance (Holt and Lambourne, 2008) as well as no adverse effect (Samuel et al., 2008; Torres et al., 2008; Unick et al., 2005; Wong et al., 2011). Static stretch-induced sprint performance impairments were diminished following 6 weeks of static stretch and sprint training (Chaouachi et al., 2008). Furthermore, 3 days of static stretching with aerobic endurance exercises did not adversely affect repeated sprint abilities (Wong et al., 2011).

Much of the research would suggest that combining static and dynamic stretching may attenuate the deleterious effects of the static stretching within a warm-up (Behm and Chaouachi, 2011). For example, a group of elite athletes demonstrated no deleterious effects from sequencing static, dynamic stretches and different intensities of stretch (eight combinations) on sprint, agility and jump performance (Chaouachi et al., 2010). Similarly, Gelen (2010) combined static and dynamic stretching with a prior aerobic warm-up and found no adverse effects upon sprint time, soccer dribbling ability or soccer penalty kick distance. Although there are discrepancies whether dynamic stretching improves or has no effect on performance there are no studies to our knowledge that report dynamic stretch-induced impairments to subsequent performance.

Hence, why even consider including static stretching in a warm-up? Murphy et al. (2010) suggests that there are a number of sports where improved static flexibility could augment performance. A goalie in ice hockey must abduct their legs when in a butterfly position, gymnasts perform a split position, wrestling, martial arts, synchronized swimming, figure skating, are examples of the necessity of a pronounced static range of motion. Some dynamic stretching studies have reported similar increases in static flexibility as static stretching (Beedle and Mann, 2007; Herman and Smith, 2008), but other studies have indicated that dynamic stretching is not as effective at increasing static flexibility as static stretching (Covert et al., 2010; O'Sullivan et al., 2009). Hence, it could be important to include static stretching for sport specific flexibility.

Most of the stretching studies conducted in the past 15 years have not included all components of the typical warm-up. Whereas, many investigations have included an initial general aerobic activity followed by a stretching routine, far fewer have integrated the sport specific activities that normally follow the first two warm-up components. A few warm-up studies have included resistance exercises to the warm-up to potentially provide an augmentation of subsequent performance. Whereas, studies implementing weighted vests (Faigenbaum et al., 2006), squats with 20% of body mass (Needham et al., 2009), and resisted leg presses (Abad et al., 2011) have shown improvements in subsequent vertical jump height and leg press strength respectively, other studies that added resistance exercises reported no augmentation of subsequent jump performance (Turki et al., 2011). Similarly, there are reports of improved performance with the addition of

specific dynamic warm-up activities such as jumps (Vetter, 2007; Young and Behm, 2002) and volleyball activities (Saez et al., 2007). Conversely, there were no significantly greater improvements in vertical and long jump performance with children who added jumps to the dynamic stretching routine versus just performing dynamic stretches. Thus further research is necessary to clarify whether sport specific activities within a warm-up can either suppress the often-reported static stretch-induced impairments or augment subsequent performance when performed in conjunction with dynamic stretching.

The purpose of the present study was to compare the effects of static and dynamic stretching on subsequent performance following general and activity specific warm ups. The experimental protocol was designed to be similar to practical warm-up that is used with actual training conditions. It was hypothesized that the inclusion of an activity specific component to the warm-up would improve subsequent performance. A second hypothesis was that the static stretching component would impair subsequent performance compared to dynamic stretching.

Methods

Subjects

Nine male (27.8 ± 8.4 years, 90.6 ± 11.1 kg, 1.79 ± 0.06 m) and 10 female (22.2 ± 3.3 years, 55.8 ± 5.2 kg, 1.65 ± 0.08 m) university students and staff volunteered for the experiment. All participants regularly trained either aerobically or with resistance training and were actively involved in recreational or competitive sports. Participants represented a variety of sports including squash, hockey, resistance training, and cross-country running. Frequency and duration of participation ranged from 3-5 days per week and 45-90 minutes per session. They were verbally informed of the protocol, read and signed a consent form. Each participant also read and signed a Physical Activity Participation Questionnaire (PAR-Q: Canadian Society for Exercise Physiology) to ensure their health status was adequate for participation in the study. The Memorial University of Newfoundland Human Investigations Committee sanctioned the study.

Independent variables

Participants were required to complete four warm-up conditions. The order of the conditions was randomized.

1. General warm-up with dynamic stretch: This condition had participants run around a 200-meter track for 5 minutes maintaining a heart rate of 70% of the individual's age predicted maximal heart rate. Heart rate was monitored with a heart rate monitor (Polar A1 heart rate monitor; Woodbury NY) secured around the participant's chest at the level of the xiphoid process. Participants were also informed and monitored by the investigator to ensure a light perspiration occurred at the completion of the run in order to ensure an increase in core temperature. The dynamic stretching included 3 sets of 30 seconds each of hip extension / flexion, adduction / abduction with fully extended legs, trunk circles and passive ankle rotation. All stretches were performed dynamically to full ROM at a moderate speed of approximately 1 Hz (approximately 30

repetitions per set) such that there was continuous motion, but without enough speed to force the stretch beyond normal ROM. Participants were instructed not to exceed their point of discomfort or a pain threshold when performing ROM exercises. The rate of dynamic stretching was monitored with a metronome.

2. General and specific warm-up with dynamic stretch: This condition followed the same protocol as condition 1, however there was an addition of a sport specific warm-up, which included three-sprint specific exercises performed in random order. These exercise included high knee (hip flexion to approximately 90°) skipping, high knee (hip flexion to approximately 90°) running, and butt kick (knee flexion with the objective to touch the buttocks with the heel) running. Each task was performed over a 20-metre distance and repeated twice before moving onto the next task.

3. General warm-up with static stretch: This condition followed the same guidelines for the general warm-up as with the previously described conditions. Static stretching exercises were implemented with no subsequent specific warm-up activities (running and skipping). Following the general warm-up participants performed a series of static stretches in randomized order including supine partner assisted hamstring stretch (hip flexion with extended leg), kneeling partner assisted quadriceps stretch (front knee and hip flexed at 90° , rear knee on floor and flexed to maximum ROM), seated partner assisted low back stretch (hip flexion to maximum ROM with legs partially abducted and knees slightly flexed), and standing wall supported calf stretch with the other leg in dorsiflexion. All stretches were repeated for 3 sets of 30 seconds and held at the point of mild discomfort.

General and specific warm-up with static stretch: This condition followed the general warm-up outlined in all 3 previous conditions followed by the specific warm-up used in condition 2 and the static stretching from condition 3.

Performance tests

The order of testing began with movement time (MT) followed by countermovement jump (CMJ), sit and reach flexibility and concluded with repeated sprints. These tests were not conducted in a randomized order as the MT could be affected by the possible potentiating effects of the CMJ or possible fatiguing effects of the repeated sprints. Furthermore, the CMJ height could be affected by the possibility of fatigue associated with the repeated sprints. Hence a consistent order of testing was felt to be more reliable than a randomized order in this experiment. Testing was conducted prior to the warm-up conditions and commenced 3 minutes following the interventions (post-warm-up).

MT was measured with a contact mat and a light gate apparatus. The subject was to activate the timer by touching their foot to the contact mat and then immediately flex the hip with maximal acceleration in a kicking motion through a light gate set at 0.5 meters from the mat. This test was utilized to simulate the forward stride during the sprint action. Data was collected using the Innervations © Kinematic Measurement System, (v. 2004.2.0) on

a laptop computer. This process was repeated 3 times with the fastest movement time used for analysis.

CMJ jump height was measured using a contact mat, which calculated flight time. Data was collected using the Innervations © Kinematic Measurement System, (v. 2004.2.0) on a laptop computer. Participants were instructed to jump as high as they could immediately following a semi-squat counter movement. During the countermovement, participants used their preferred technique, allowing them to swing the arms. None of the participants during the descent phase brought their thighs lower than parallel to the floor. During the jump phase, the arms were allowed to full extend above the head (Behm et al., 2004; Kean et al., 2006; Power et al., 2004). This process was repeated 2 times with the highest jump used for analysis.

Using a sit and reach testing device (Acuflex 1, Novel products Inc., USA), participants sat with leg straight (extended) and feet flat against the sit and reach device. They exhaled and stretched forward as far as possible with one hand over the other and finger tips in line and held the end point for 2 seconds. This process was repeated 2 times with the greatest ROM used for analysis. This is the protocol prescribed by the Canadian Society for Exercise Physiology (CSEP) to determine flexibility and used in other studies from this laboratory (Behm et al., 2006; Power et al., 2004).

For the repeated 20m sprints, participants ran six 20 metre sprints with 30s recovery between each sprint. Participants started one stride behind the contact mat. Sprint time over the 20 meters was measured from the contact with the switch mat until passing through the light gate apparatus at 20 metres. Only one series of 6 sprints was performed due to the possibility of fatigue. Data was collected using the Innervations © Kinematic Measurement System, (v. 2004.2.0) on a laptop computer.

Statistical analysis

A 2 way repeated measures ANOVA (4x2) with factors being conditions (dynamic stretch with prior general warm-up, static stretch with prior general warm-up, dynamic stretch with general and specific warm-up, and static stretch with general and specific warm-up) and time (pre- and post-warm-up) was performed to determine if significant differences existed between the warm-up conditions. (GB Stat Dynamic Microsystems, Silver Springs Maryland USA). An alpha level of $p < 0.05$ was considered statistically significant. If significant difference were detected, a Tukeys –Kramer post-hoc procedure was used to identify the significant main effects and interactions. All data are reported as means and standard deviations. Between test reliability was analyzed by comparing the pre-test measures of the four interventions, with an intra-class correlation coefficient (ICC) at a 95% confidence interval. Effect sizes (ES = mean change / standard deviation of the sample scores) were also calculated and reported. Cohen applied qualitative descriptors for the effect sizes with ratios of <0.41 , $0.41-0.7$, and >0.7 indicating small, moderate and large changes respectively.

Results

All measures exhibited excellent reliability with ICC of 0.96, 0.92, 0.90, 0.87 for the MT, sit and reach test, CMJ and repeated sprints respectively. There were no significant main effects or interactions involving the experimental conditions for MT and CMJ height.

Sit and reach

There was a significant main effect for conditions ($p = 0.0083$; $f = 24.81$, ES = 0.33) with both static stretch conditions providing an average 2.8% greater sit and reach score than two conditions involving dynamic stretch (Figure 1).

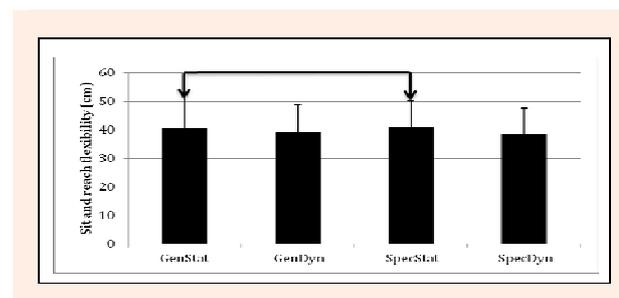


Figure 1. Figure illustrates a significant ($p = 0.0083$) main interaction for condition. Columns and bars represent means and SD respectively. Arrows indicate the significantly greater sit and reach scores for the general (GenStat) and specific (SpecStat) static stretch conditions versus the dynamic stretching conditions. The acronyms are defined as follows: GenStat: general warm-up with static stretching, SpecStat: general and specific warm-up with static stretching, Gen Dyn: general warm-up with dynamic stretching, SpecDyn: general and specific warm-up with dynamic stretching.

Sprint time

There were significant main effects for condition, and sprint factors. A main effect for condition ($p = 0.0013$; $f = 37.84$, ES = 0.36) indicated that the warm-ups involving a specific warm-up component resulted in a 0.94% improvement in sprint time versus the warm-ups involving only a general warm-up (Figure 2). A main effect for sprint time ($p = 0.007$; $f = 20.34$, ES = 0.13) showed a fatigue effect with the fifth sprint being 1.2% significantly slower than the second sprint (Table 1).

Table 1. Mean (\pm SD) sprint times collapsed over gender.

Sprint	Males and Females combined averages
1	3.40 (.35)
2	3.39 (.36) *
3	3.40 (.38)
4	3.42 (.37)
5	3.44 (.38) *
6	3.41 (.36)

* indicate a significant ($p = 0.007$) difference between the second and fifth sprint.

Discussion

The most important findings of the present study were that the addition of an activity specific warm-up enhanced sprint performance and that the static stretching protocol resulted in a greater sit and reach score than dynamic stretching.

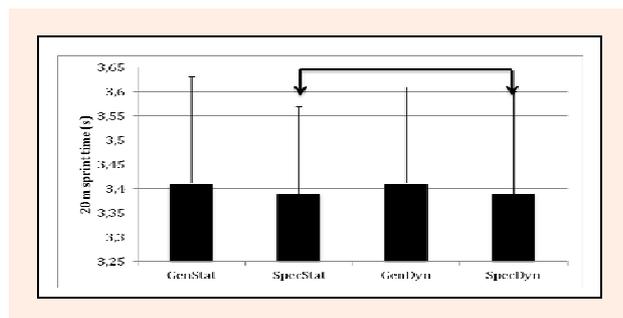


Figure 2. Figure illustrates a significant ($p = 0.0013$) main effect for condition. Column and bars represent mean and SD respectively. Arrows indicate a significantly decreased sprint time between a general and specific warm-up with static stretching versus a general and specific warm-up with dynamic stretching. The acronyms are defined as follows: GenStat: general warm-up with static stretching, SpecStat: general and specific warm-up with static stretching, Gen Dyn: general warm-up with dynamic stretching, SpecDyn: general and specific warm-up with dynamic stretching.

In accordance with the first hypothesis, whether the activity specific warm-up protocol was implemented with static or dynamic stretching, there was a significant improvement in sprint time. A similar intervention was used by Rosenbaum et al. (1995) who reported a decreased time to peak force with a tendon tap of the triceps surae following static stretching and treadmill running warm-up and an increased time to peak force when measured after static stretching alone. It seems that the addition of a specific warm-up helped to minimize or negate the performance decrements of static stretching alone. Skof and Strojnik (2007) found that the addition of sprinting and bounding to a warm-up consisting of slow running and stretching resulted in an increase in muscle activation when compared to slow running and stretching alone. Young and Behm (2002) conducted a study involving a variety of warm-ups including a general aerobic warm-up (4 minute run), static stretching alone, general warm-up and static stretch, and a full warm-up with a general warm-up (4 min run), static stretch and practice CMJ. Generally the warm-ups that involved static stretching resulted in the lowest scores whereas the general warm-up or general warm-up, static stretch and specific warm-up (CMJ) condition produced the highest explosive force scores. Hence, similar to the present study, specific warm-up activities enhanced performance and minimized the expected static stretch deficits.

The lack of static stretching-induced decrements may also be related to the duration of stretching. Behm and Chaouachi (2011) in an extensive review identified that a duration of greater than 90s of static stretching was a common duration in the literature where static stretching generally produced impairments. Although the literature was not unanimous, a greater proportion of studies that utilized static stretching for less than 90s did not exhibit subsequent performance impairments. A similar conclusion was published in a review by Kay and Blazevich (2012) who indicated that the detrimental effects of static stretching are mainly attributed to static stretch durations of 60s or greater. The 3 sets of 30s stretches held to the point of mild discomfort used in the present study may

not have elicited substantial detrimental effects when combined with general and specific warm-up activities.

The improved sprint performance following the addition of the activity specific warm up may be attributed to a variety of physiological factors. The additional warm up time may have led to a further increase in muscle temperature, nerve conduction velocity, and muscle enzymatic cycling, along with a decrease in muscle viscosity (Bishop, 2003). Also, as indicated by Behm and Chaouachi (2011) and Turki et al. (2011) post activation potentiation (PAP) may be induced even with lower intensity dynamic movements. Turki et al. (2011) reported that performing 1- 2 sets of active dynamic stretches in a warm-up enhanced 20-m sprint performance, which they attributed to PAP. PAP is suggested to increase cross bridge cycling via increased myosin phosphorylation of the regulatory light chains (Tillin and Bishop, 2009). There may also be neural potentiation resulting in a decrease of fast twitch motor unit thresholds resulting in an increase in motor unit recruitment and firing frequency (Layec et al., 2009). The increased firing frequency would be related to an increase rate of force development (Miller et al., 1981).

It could be argued that an approximately 1% statistically significant improvement in sprint time is not clinically meaningful. An effect size calculation for this measure produced a ratio of 0.36, which is described as a small but not trivial magnitude of change (Rhea, 2004). Whereas an approximate 1% change in sprint time might be inconsequential for a recreational athlete, it could prove to be very consequential to an elite athlete.

Significant differences were not found during for the CMJ test. This is consistent with results from other similar studies (Knudson et al. 2001, Power et al. 2004, Unick et al. 2005) While others (Bradley et al., 2007) noted a decrease in vertical jump performance following a static stretching condition there was a less significant decrease in performance following ballistic stretching. Perrier et al. (2011) found that dynamic stretch yielded significantly ($p=0.004$) greater CMJ results than static stretching, although static stretching was not significantly different from the no stretch protocol. The warm-up protocols in the present study had no effect on CMJ performance, however it should be noted that a static stretch only (no general warm-up) group was not used in the present study. This lack of change in CMJ height with the specific warm-up activities may be due to a change in jump strategy as the musculotendonous unit (MTU) becomes more compliant (McNeal et al., 2010). Power et al. (2004) concluded that a more compliant MTU might be more beneficial when higher forces are involved. The Power et al. study did not report any CMJ impairment following static stretching but did report an increase in contact time (i.e. change in jump strategy). Conversely, Holt and Lambourne (2008) observed a decrease in vertical jump performance when static stretch was used following a general warm-up. Similarly Needham et al. (2009) observed superior sprint and jump performance when dynamic stretching was used but a decrement with static stretching. The Needham et al. study however used 10 minutes of static stretching whereas the current study used 3 repeti-

tions of 30s. This significant time difference may account for the difference in performance results.

When static stretching was implemented within the testing conditions, sit and reach scores exceeded scores attained by conditions using dynamic stretching. The warm-up protocols (general versus general and specific) implemented in the present study had no additional effects on sit and reach results. The superiority of static stretching for increasing static ROM concurs with a number of other studies (Bandy and Irion, 1994, Power et al., 2004, Beedle and Mann, 2007, O'Sullivan et al., 2009, Covert et al., 2010). Alternatively other studies (Amiri-Khorasani et al., 2011, Perrier et al., 2011, Samukawa et al., 2011) have indicated that dynamic stretching can produce equal or greater results in dynamic and static ROM tests. Perrier et al. (2011) compared the effects of static and dynamic stretching on sit and reach flexibility and unlike the present study found no difference in sit and reach score between static and dynamic treatments. Static stretching is known to increase muscle compliance to stretch as well as decrease muscle stiffness and viscosity (Behm and Chaouachi 2011). Magnusson et al. (1996) indicated that increased flexibility could be primarily attributed to an increase in stretching tolerance. Neural effects may also play a role as Avela (1999) reported a decreased H-reflex contributing to subsequent muscle relaxation due to decreased reflex activity. Although the precise mechanisms underlying the superiority of static stretching for ROM increases in the present study cannot be verified, the similarity of the static stretch intervention and sit and reach testing procedure may play a significant role. Following the concept of mode or testing specificity (Behm and Sale, 1993), the static stretching protocol in the present study more closely resembled the sit and reach test than the dynamic stretching exercises.

Conclusion

Overall the present study has demonstrated that the use of an activity specific warm-up may be useful to enhance sprint performance even with the inclusion of static stretching. Interestingly the study has also shown that static stretching had superior results for improving static sit and reach ROM. Such results would support the use of relatively short duration (90s) static stretching within an activity specific warm-up to ensure maximal ROM in conjunction with enhanced sprint performance.

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Key points

- Activity specific warm-up may improve sprint performance.
- Static stretching was more effective than dynamic stretching for increasing static range of motion.
- There was no effect of the warm-up protocols on countermovement jump height or movement time.

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