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Original Article

Effects of static stretching following a dynamic warm-up on speed, agility and power

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ABSTRACT

Bishop D, Middleton G. Effects of static stretching following a dynamic warm-up on speed, agility and power. *J. Hum. Sport Exerc.* Vol.8, No. 2, pp. 391-400, 2013. Static stretching prior to sport has been shown to decrease force production in comparison to the increasing popularity of dynamic warm-up methods. However some athletes continue to use a bout of static stretching following dynamic methods. The purpose of this study was to investigate the effects on speed, agility and power following a period of additional static stretching following a dynamic warm-up routine. Twenty-five male University students who participated in team sports performed two warm-up protocols concentrating on the lower body one week apart through a randomised cross over design. The dynamic warm-up (DW) protocol used a series of specific progressive exercises lasting 10 minutes over a distance of 20m. The dynamic warm-up plus static stretching (DWS) protocol used the same DW protocol followed by a 5 minute period during which 7 muscle groups were stretched. Following each warm-up the subjects performed a countermovement vertical jump, 20m sprint and Illinois agility test, 1 minute apart. The results demonstrated no significant differences in speed, agility and jump performance following the two protocols DW and DWS. The study concludes that performing static stretching following a dynamic warm-up prior to performance does not significantly affect speed, agility and vertical jump performance. **Key words**: PERFORMANCE ENHANCEMENT, WARM-UP, VERTICAL JUMP, 20M SPRINT, ILLINOIS AGILITY.

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INTRODUCTION

The purpose of the pre-competition and training warm-up is to prepare the athlete for the demands of the competition. A well-designed warm-up can assist the athlete in mentally focussing on the upcoming task and bring about physiological changes to optimise performance (Swanson, 2006).

Bishop, (2003) identified that the majority of the effects of a warm-up can be attributed to temperature-related mechanisms such as; decreased stiffness, increased nerve conduction rate, altered force-velocity relationship, increased anaerobic energy provision and increased thermoregulatory strain. In addition to the temperature-related mechanisms, Bishop's (2003) review outlined roles of non-temperature related factors; blood flow to the muscles, elevation of baseline oxygen consumption and postactivation potentiation. Achieved through continuous cardiovascular movements, both temperature and non-temperature related mechanisms are activated during a sufficient warm-up (Bishop, 2003).

Traditional warm-up methods include a static stretching (SS) component, however the effects of incorporating this type of stretching in the warm-up routine and whether it has a detrimental effect on force and power production has been questioned (Young and Behm, 2003; Power et al., 2004; Yamaguchi & Ishii, 2005; Bradley et al., 2006; Stewart et al., 2007; Fletcher and Anness, 2007; Samuel et al., 2008; Sayers et al., 2008). The decrease in force and power production due to static stretching has been attributed to an alteration of the visco-elastic properties within the muscles, resulting in decreased stiffness of the musculo-tendinous unit (Avela et al., 1999; Kokkonen et al., 1998). This theory has been opposed by Knudson, (2001) who believes the changes are due to acute neural inhibition, resulting in an increase in autogenic inhibition which decreases neural drive to the muscle, leading to a decrease in muscle activation. The decrease in force and power production due to static stretching has been attributed to an alteration of the visco-elastic properties within the muscles, resulting in a decreased stiffness of the musculo-tendinous unit (Avela et al., 1999; Kokkonen et al., 1998) This theory has been opposed by Knudson, (2001) who believes the changes are due to acute neural inhibition, resulting in an increase in autogenic inhibition which decreases neural drive to the muscle, leading to a decrease in muscle activation.

Previous studies (Power et al., 2004; Yamaguchi & Ishii, 2005; Bradley et al., 2006; Stewart et al., 2007; Samuel et al., 2008; Sayers et al., 2008) into the impact of SS on performance frequently utilise methods that do not accurately replicate normal pre-competition routines. Young, (2007) stressed the importance of investigating the role of SS using protocols that are realistic and reflective of current practice. Studies demonstrating impairments due to SS have tended to use at least 2 minutes of total time under stretch per muscle group (Young, 2007; Little & Williams, 2006; Taylor et al., 2009). The excessive time provided for the stretching routines may cause a reduction in core temperature of the muscles and alter the visco-elastic behaviour of the muscle and tendon (Taylor et al., 2009). A number of studies that have used more appropriate protocols, either isolating SS following a general warm-up or in combination with sports specific warm-up components (Young & Behm, 2003; Young, 2007; Little & Williams, 2006; Taylor et al., 2009). These studies revealed no impairments in performance due to SS. This may either be as a result of following realistic SS protocols, or alternatively, as a result of the dynamic warm-up removing or reducing the detrimental effects induced by SS (Chaouachi et al., 2010). Furthermore, Sim et al., (2009) identified that the order of dynamic activities and SS in warm-up's needs further investigation to determine optimal pregame preparation.

Positive benefits with the sole use of dynamic style warm-ups have been established in performance tests requiring explosive force production (Young et al., 2004; Fletcher & Jones, 2004; Little & Williams, 2006;

Fletcher & Anness, 2007; Hough et al., 2009; McMillian et al., 2009; Taylor et al., 2009; Amiri-khorasani et al., 2010). Hence the traditional cardiovascular component and SS routines have been replaced in favour of dynamic warm-up methods due to the reported benefits to short-term force production (Fletcher & Anness, 2007). Dynamic warm-up protocols provide temperature related mechanisms similar to traditional cardiovascular components of a warm-up and require the muscles to contract in sequence affecting the central programming of the muscle contraction/coordination (McMillian et al., 2009). Mann & Jones, (1999) suggest that the key attributes of dynamic stretching include enhanced motor unit excitability and improved kinaesthetic sense, leading to improved proprio-ception and pre-activation.

Whilst the literature illustrates that dynamic stretching has demonstrated improvements in performance in comparison to SS, interestingly some studies have suggested that dynamic stretching is not as effective in increasing static flexibility as SS (Chan et al. 2001; Davis et al. 2005; O'Sullivan et al. 2009; Covert et al. 2010). Murphy et al., (2010) argue that there is a role for SS in a warm-up given the numerous sporting movements which incorporate static flexibility, such as the ability of a goaltender in ice hockey to maximally abduct his or her leg. Secondly, from an applied perspective, the transition from traditional warm-up practices to adopting dynamic style warm-up's has left some athletes with feelings of psychological 'unease' when performing warm-ups without undertaking SS (Nelson et al., 2005, Young (2007). To date only a small number of paper's (Sim et al., 2009; Chaouachi et al., 2010; Kistler et al., 2010) have looked at the impact of SS post dynamic warm-up and the studies have found no significant differences in sprint performance (Sim et al., 2009; Chaouachi et al., 2010; Kistler et al., 2010) or agility and jump performance (Chaouachi et al., 2010). The benefits of a warm-up prior to sports training or competition remain universally accepted, but the subsequent use and or combination of SS with sports (dynamic) specific warm-ups on performance measures and flexibility is still not fully understood (Young, 2007).

The purpose of this study is to explore the effects of adding additional SS to a dynamic warm-up routine on speed, agility and power on team sport players who want to increase flexibility and maintain effective power production during a warm-up. It is hypothesised that there will be no performance detriment upon adding SS to a dynamic warm-up.

MATERIAL AND METHODS

Subjects

25 male University sports students who participate in competitive team sports volunteered to participate in the study (age, 20.25 ± 1.28(y); height 1.84 ± 0.072(m) and body mass 77.56 ± 13.7(kg); mean ± SD). Testing was in accordance with and approved by the Institutional Ethics Committee. All participants received a clear explanation of the study, including the risks and benefits of participation and written informed consent for testing was obtained from all participants.

Experimental approach to the problem

The study was a randomised, counterbalanced, within-subjects design. The independent variable was the type of warm-up method used prior to the performance testing. The dependent variables were scores on three performance measures: a 20 m sprint; an Illinois agility test and a Countermovement Jump (CMJ) test, used to assess speed, agility and power respectively. The three tests were chosen as they replicate the movement patterns found within team sports and are consistently used as determinants of performance (Church et al., 2001; Young & Behm, 2003; Power et al., 2004; Fletcher & Jones, 2004; Yamaguchi & Ishii, 2005; Bradley et al., 2006; Little & Williams, 2006; Samuel et al., 2008; McMillian et al., 2009; Sim et al., 2009; Taylor et al., 2009; Chaouachi et al., 2010; Kistler et al., 2010). The 20m Sprint and Illinois agility time, were measured using electronic timing gates (Smart Speed, Fusion Sport, New Zealand). To assess jumping performance the participants performed a maximal CMJ using a Just Jump Mat (Probotics Inc, USA). The participants were instructed to stand with feet approx shoulder width apart, perform a CMJ to a self selected depth and jump for a maximal height (reliability ± 0.5in) (Church et al., 2001). The test, re-test reliability for each test was calculated using Technical Error of Measurement (TEM) equation at 0.09% for the 20m sprint, 0.26% for the CMJ and 0.07% for the Ilinios Agility test.

Procedure

Participants were highly familiar with the warm-up methods and performance measures to be used in the study and undertook an additional familiarisation session to outline the protocols of the experiment. The experimental design consisted of two sessions scheduled a week apart, at the same time of day. Participants were asked to maintain habitual training patterns to minimise training effects on performance. The sessions were counterbalanced to minimise any learning effect from previous testing sessions, using a within subject design. All warm-up procedures and testing was performed in an indoor sports facility to eliminate the effects of wind resistance or inclement weather.

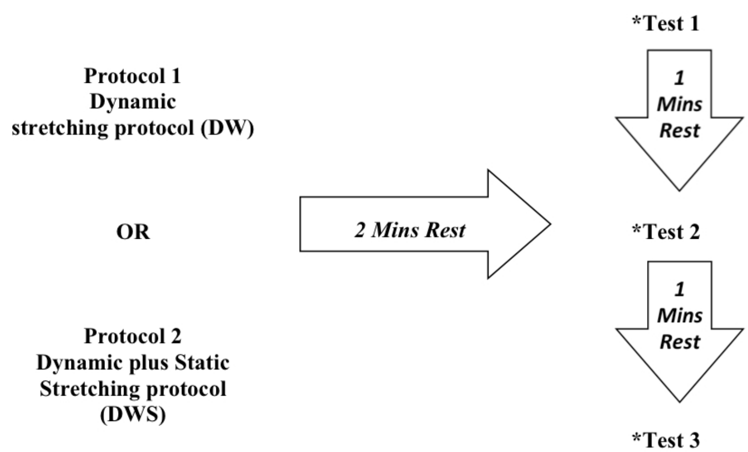

Figure 1. *Schematic representation of the study design and testing procedures used*
*The order of the performance tests (20m Sprint, Illinois agility and vertical jump) was conducted and randomised for each participant. The order was maintained for both protocols.

The warm-up protocols concentrated on the quadriceps, hamstrings, gastrocnemius, soleus, gluteals, adductors and hip flexors. The Dynamic Warm-up (DW) protocol used a series of specific progressive exercises lasting a total of 10 minutes over a distance of 20m with a jog recovery (see table 1 for full details). The Dynamic Warm-up plus Static stretching (DWS) protocol used the same DW protocol followed by a 5 minute period during which 7 muscles groups were stretched to a point of discomfort for 20 seconds (Young, 2007) (see table 2 for full details).

Table 1. *Dynamic Stretching Protocol (DW)*

Dynamic Flexibility Protocol	Distance & Reps
Ankle Flicks - Gentle skips plantar flexing the ankles	**20m x 1**
Jogging Skips - Rising to the toes, maintaining good posture with use of arms to counterbalance.	**20m x 1**
High Knees - Forwards running with exaggerated knee lift driving of the arms, fast legs slow travel	**20m x 1**
Heel Flicks - forwards running with exaggerated knee flexion driving the arms, fast legs slow travel.	**20m x 1**
Small 2 footed Jumps - feet shoulder width apart, flexing at knees then extending jumping off the ground and repeating	**20m x 1**
Lateral running - step laterally driving the arms and legs, ensure feet do not cross (Repeat leading with opposite foot)	**20m x 2**
Squats - step laterally to feet shoulder width apart and then gradually squat while keeping the trunk stable, extend forcefully into standing and repeat. Repeat leading with the opposite foot	**20m x 2**
Carioca - sideways running, trail leg to move past the lead leg, once behind then in front, with exaggerated hip rotation (Repeat leading with the opposite foot)	**20m x 2**
High Knee Skip - as with jogging skips, but now extend on to the toes forcefully and leave the ground, driving with the arms and raising opposite knee (emphasis on vertical height)	**20m x 1**
Zig Zags - Knees flexed 2 steps to the left followed by 2 steps to the right repeated over 20m	**20m x 1**
Russian Walk – flexing at the hip then extending at the knee till the leg is fully extended parallel to the floor, pull the leg from an extended position back to the floor with toes pointing upwards	**20m x 1**
Two High Jumps, one small - flexing the knees perform two vertical jumps advancing forward followed by one small vertical jump, using the arms –repeated over 20m	**20m x 1**
Open, close gate - abduct the thigh laterally from the hip and rotate the thigh forwards, followed by same action on the opposite leg repeated over 20m –repeat moving backwards lifting and flexing the knee and rotating at the hip to an abducted position followed by same action on opposite leg	**20m x 2**
Lunges - step through with one foot, flexing at the knees and lowering the body towards the floor keep good posture, extend to a standing position and step through with opposite and repeat	**20m x 1**
Sprints 70, 80 & 90% of Max Speed – 20 metre sprints at increased intensity levels of perceived maximum speed	**20m x 3**

Table 2. *Static Stretching Protocol*

Static Stretching Protocol (7 x 20 second stretches to a position of mild discomfort repeated unilaterally were required)
Quadriceps – subjects stand on one leg with a posterior pelvic tilt and with one hand against the wall for balance, grasping their foot to bring the knee into flexion as far as possible, keeping the knee perpendicular to the floor until tension was felt in the quadriceps (repeat on opposite leg)
Hamstrings – take a step forward with the left leg and reach toward the left foot by bending at the waist. Both knees are slightly bent and the arms are straight on either side of the forward leg. The trunk remains straight with the head in a neutral position (repeat on opposite side)
Gastrocnemius – standing close to a wall step forward 40 - 50cm, bending at the waist reach forward towards the wall flexing at the left knee until tension is felt in the right gastrocemnius maintaining heel contact with the floor in both feet (repeat on opposite side)
Soleus – take a step forward with the left leg, flex at both knees to a semi squatted position and until tension is felt in the right soleus (repeat on opposite side)
Gluteals – in a seated position, cross the right ankle over the left thigh. Grasp the right knee with both hands and pull it towards the left shoulder until tension is felt in the gluteals (repeat for opposite side)
Adductors – in a seated position, flex both knees placing the soles of each foot together and abduct the knees towards the floor until tension is felt in the adductors
Hip Flexors – take a step forward 40 – 50cm with the left leg and lower the body towards the ground flexing at both knees and posteriorly tilting the pelvis until tension is felt in the right hip flexor (repeat on opposite side)

After an initial rest period of 2 minutes the participants performed a, 20m sprint, a Illinois agility test and a CMJ with a one minute rest period between each performance test. The order in which the performance measures were conducted was randomised for each participant; for an individual participant the order was maintained across both protocols.

Statistical Analysis

Paired t-tests were performed to determine if there were any differences in the performance variables measured between a dynamic warm-up plus SS and a dynamic warm-up alone. (SPSS for windows v17, SPSS Inc, Chicago IL, USA). Prior to the completion of the inferential analysis, a Shaprio-Wilks test for normality was conducted and found to have an alpha level of $p > 0.05$.

RESULTS

The dependent t-tests demonstrated a non-significant effect of additional static stretching following a dynamic warm-up. The mean performance data (Table 3) demonstrated that the DWS routine resulted in a trend of reduced mean performance in all the performance measures; 20m sprint -0.95% ($p > 0.05$; $t = -1.41$ df =24), CMJ -3.6% ($p > 0.05$; $t = 1.534$, df =24) and Illinois agility -0.06% ($p > 0.05$; $t = -0.418$, df = 24). However the individual participant data was not uniform across participants in any of the performance measures, see table 4 for details.

Table 3. *Scores on the three performance tests following the two warm-up conditions DW and DWS. All scores are mean ± SD.*

Performance Measure	Dynamic Warm-up (DW)	Dynamic Warm-up plus Static Stretching (DWS)
20m Sprint	3.15s ± 0.15	3.18s ± 0.13
Illinois Agility	16.66s ± 0.60	16.68s ± 0.61
CMJ	0.55m ± 0.07	0.53m ± 0.08

Table 4. *Percentage of participants showing a increase, a decrease, or no change in performance following the addition of static stretching*

Performance Measure	Decrease in Performance	No Change	Increase in Performance
20m Sprint	48%	8%	44%
Illinois Agility	60%	0%	40%
CMJ	48%	24%	28%

DISCUSSION

Whilst many researchers have shown that SS can inhibit strength, power and speed performance (Power et al., 2004; Yamaguchi & Ishii, 2005; Bradley et al., 2006; Stewart et al., 2007; Samuel et al., 2008; Sayers et al., 2008), the warm-up protocols used have not always replicated current practice in preparing for explosive sports performance. The stretching protocols employed have often provided in excess of 2 minutes SS per muscle group, or used SS in isolation. In addition it has been identified that dynamic warm-up methods whilst proficient in improving performance (Young et al., 2004; Fletcher & Jones, 2004; Little & Williams, 2006; Fletcher & Anness, 2007; Hough et al., 2009; McMillian et al., 2009; Taylor et al., 2009; Amiri-khorasani et al., 2010) are not as effective in increasing static flexibility in comparison to SS (Chan et al. 2001; Davis et al. 2005; O'Sullivan et al. 2009; Covert et al. 2010). It has been argued that flexibility is an essential performance component in team sports and should therefore be incorporated into the warm-up routine (Murphy et al., 2010).

The current study implemented a protocol replicating warm-up patterns performed by athletes within team sports, combining dynamic and SS routines. The findings suggest that there are no confounding effects of performing static stretching following a dynamic warm-up on 20m sprint, Illinois agility or CMJ performance. The results confirm the findings of similar studies that have found numerical differences in performance but no significant differences in adding static stretching to dynamic warm-up routines on sprint, agility and jump performance (Sim et al., 2009; Chaouachi et al., 2010).

A small mean numerical reduction in performance was identified in all performance measures however the response within the 25 participants did not demonstrate any consistent positive or negative trends following the additional static stretching, possibly suggesting that individuals respond differently to combining dynamic and SS routines. Chaouachi et al. (2010) suggested that there is evidence to support that highly trained individuals are more resistant to stretch-induced deficits as shown in a number of other studies (Unick et al., 2005; Egan et al., 2006; Little & Williams, 2006). Furthermore Chaouachi et al. (2008) found that 6 weeks of sprint and stretching training made participants more resistant to stretch induced deficits.

Previous research by Young & Behm, (2003); Little & Williams, (2006); Taylor et al., (2009) found that practice attempts of the required tasks or sports specific dynamic movements may offset any potential negative effects of static stretching when included prior to a dynamic warm-up. The current study has identified that any negative effects of SS may also be reduced when the SS is placed after the dynamic warm-up which concurs with studies who have undertaken similar warm-up based protocols (Sim et al., 2009; Chaouachi et al., 2010). Sim et al., (2009) found no statistical significance when comparing different dynamic and SS combinations, however the findings did show a small performance impairment when comparing a dynamic warm-up alone to warm-ups incorporating SS pre or post dynamic exercises. Furthermore the warm-up that incorporated SS following the dynamic warm-up performed worst with a 0.3% - 0.9% impairment in performance. Chaouachi et al. (2010) identified similar findings of small performance impairments over sprint, agility and jump performance.

Research examining the effect of SS on performance is equivocal in relation to performance benefits (Young & Behm, 2003; Fletcher & Jones, 2004; Power et al., 2004; Young et al., 2004; Yamaguchi & Ishii, 2005; Bradley et al., 2006; Fletcher & Anness, 2006; Little & Williams, 2006; Stewart et al., 2007; Samuel et al., 2008; Sayers et al., 2008; Taylor et al., 2009). However there is very little evidence to support any notion that performance can be improved through SS within a warm-up. Therefore, the main argument that has been put forward for inclusion of SS in the warm-up is two-fold: firstly to enhance static flexibility within sports where a performer is required to position themselves at the limits of static range of motion; secondly due to a perceived psychological need to increase static flexibility levels ready for the performance demands (Young, 2007) or due to performers feeling uneasy prior to competing when SS is omitted (Nelson et al., 2005). The two arguments put forward are plausible explanations to the cognitive effects due to the omission of SS.

Physiologically the incorporation of SS to dynamic exercises in a warm-up is contradictory, there are no known studies that have demonstrated improvements in performance as a result of incorporating SS when compared to warm-up's including only dynamic exercises. In addition, whilst the current study and other similar studies who have combined static and dynamic protocols have not found any significant detriments in performance, small numerical detriments have been observed. SS is thought to create alterations in musculotendinous stiffness (Kokkonen et al., 1998; Avela et al., 1999) or altered reflex sensitivity and decreased muscle activation (Knudson, 2001) and therefore impact upon the transmission of forces and the rate of force transmission which are essential variables to effective sprinting and jumping performance.

Furthermore it is difficult to determine the required intensity of a stretch without quantitative measurement to determine whether an increase in range of motion is achieved and whether this is sufficient to the demands of open play in team sports. The use of SS routines also tends to last for a minimum duration of 5 - 10 minutes which is likely to induce a reduction in core and local muscle temperature which could counteract the effects of stretching (Taylor et al., 2009).

Whilst there may be a valid rationale to increasing flexibility in a warm-up, SS appears to be counterproductive in the rate of force transmission and produces performance detriments in comparison to dynamic stretching warm-up methods. The margin between winning and losing in sport is small, fractions of a second in a short sprint or loss of centimetres in jump height are essential components of sports tasks in team sports and contribute to competent performances. Moreover, there is a lack of research into the correlation between undertaking SS and the effects on required range of motion within competition or the psychological effect of not feeling ready to perform to promote its inclusion as a valid protocol.

CONCLUSIONS

The results suggest and concur with previous research that the use of SS following a dynamic warm-up in team sports does not lead to significant decreases in performance in explosive measures of sprint, agility and jumping performance. However, practitioners should consider carefully the requirements of force transmission and flexibility within their sport before determining whether to promote athletes undertaking SS in combination with a dynamic warm-up. The authors would also encourage further investigation through the use of ecologically valid protocols to fully establish the physiological and psychological effects of warm-up methods on measures of performance.

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