The Chronic Effects of Stretching on Measures of Athletic Performance

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BACKGROUND

Routine static stretching has been shown to increase flexibility, and as such it is thought to reduce the risk of injury and improve performance. For this reason, athletes, coaches and trainers traditionally incorporate static stretching exercises into their training programs, pre and/or post-exercise.

Yet, the purported benefits of stretching on injury reduction are controversial. Studies have provided mixed results on the relationship of stretching and injury prevention, with some indicating no benefit of static stretching prior to exercise. Additionally, it has been well documented that static stretching before exercise acutely decreases muscular strength, speed, and power performance. Decrementes have been observed in vertical jump height, sprint speed, reaction time, and maximum voluntary contraction. Moreover, these decrements are not limited to strength, speed and power. Wilson et. al saw decreases in endurance performance in trained runners following static stretching routines. In light of such evidence, dynamic stretching has become more and more popular in warm-ups as it has been shown to increase performance measures of strength, speed, and power when performed before physical activity.

The benefits of static stretching on injury reduction are questionable. And studies have consistently shown that static stretching prior to activity acutely decreases performance. But, there is some research showing that regular long-term static stretching can induce hypertrophy in the stretched muscles, resulting in increased strength, force, and contraction velocity. This suggests that a regular long-term static stretching program may result in increases in sports performance, mainly in strength, speed, and power. Further, it provides some reason for continuing to include static stretching in training programs. However many of these studies are
animal studies involving stretching muscles ex vivo for longer periods than used in most training programs.

Therefore, this review will explore the positive and negative effects of chronic stretching on performance since for all of its faults, athletes, coaches, and trainers still employ static stretching exercises for their presumed long term performance benefits. Our goal is to determine whether static stretching should continue to be used in the name of performance gains. As static and dynamic stretching are the most commonly used and recommended forms of stretching, we will study the long term effects of both modes. Furthermore, we will consider studies of strength, speed/acceleration, power, and endurance performance.

METHODS

PubMed and Sport Discus were searched thoroughly for articles pertinent to static and dynamic stretching and performance. A broader search was also performed using Google Scholar. Some of the key search terms used include static stretching, dynamic stretching, stretching and performance, and chronic stretching and performance. The bibliographies of these articles were then searched for further relevant articles. Articles were divided into those that researched the effects of chronic static stretching and those that researched the effects of chronic dynamic stretching.

Relevant articles consisted of those administering stretching programs of no more than one hour, at least twice per week for a minimum of three weeks. We also focused on studies with healthy populations of varying activity levels.
RESULTS

Static stretching

Twelve studies were included in this review of static stretching. Table 1 lists the findings of those used.

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Training protocol</th>
<th>Outcome</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bazett-Jones et al., 2008</td>
<td>21 D-III Women’s T&amp;F athletes</td>
<td>6 wks, 4 d/wk</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Kokkonen et al., 2007</td>
<td>40 recreationally active college students</td>
<td>10 wks, 3 d/wk</td>
<td>↑</td>
<td>↑ muscular endurance</td>
</tr>
<tr>
<td>Hunter et al., 2002</td>
<td>60 subjects w/ basketball/volleyball</td>
<td>10 wks, 4 d/wk</td>
<td>↑</td>
<td>Muscular work - No change</td>
</tr>
<tr>
<td>LaRoche et al., 2008</td>
<td>29 recreationally active males (ages 18-60)</td>
<td>4 wks, 3 d/wk</td>
<td>No change</td>
<td>Muscular work - No change</td>
</tr>
<tr>
<td>Wilson et al., 1992</td>
<td>18 male powerlifters</td>
<td>8 wks, 2 d/wk</td>
<td>↑</td>
<td>Purely concentric bench press- No change</td>
</tr>
<tr>
<td>Worrell et al., 1994</td>
<td>19 university students</td>
<td>3 wks, 5 d/wk</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Kokkonen et al., 2010</td>
<td>32 recreationally active college students</td>
<td>8 wks, 3 d/wk</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Handel et al., 1997</td>
<td>16 male athletes</td>
<td>8 wks, 3 d/wk</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Yuktasir et al., 2009</td>
<td>28 male college students</td>
<td>6 wks, 4 d/wk</td>
<td></td>
<td>Reversible muscle actions - No change</td>
</tr>
<tr>
<td>Nelson et al., 2001</td>
<td>32 recreationally active college students</td>
<td>10 wks, 3 d/wk</td>
<td></td>
<td>VO2 peak - No change</td>
</tr>
</tbody>
</table>

Torque production.

Multiple studies recorded increased isokinetic torque production as a result of flexibility training. Handel et al. observed increased isokinetic torque of the knee flexors and extensors following an eight-week static and proprioceptive neuromuscular facilitation (PNF) stretching program. Eccentric torque production increased for the knee extensors and flexors at 120º per second (23.0%, 16.5% respectively) and 60º per second (18.9%, 18.2%). Maximum isometric force increased in the knee flexors (11.3%). Concentric torque production increased only in the knee flexors, showing improvements at 60º (9.4%), 180º (8.0%), and 240º (10.4%) per second.
No change was observed in maximum isometric force of the knee extensors, concentric extensor torque production at 60º, 120º, 180º, and 240º per second, and concentric flexor torque production at 120º per second. Worrell et al.\textsuperscript{28} studied the effects of static and PNF stretching on isokinetic torque of the hamstrings on 19 university students. After a three-week investigation, increases were observed in hamstring eccentric peak torque at 60º (8.5%) and 120º (11.2%) per second, and in hamstring concentric peak torque at 120º (13.5%) per second. No change in hamstring peak torque production was observed concentrically at 60º per second. LaRoche et al.\textsuperscript{15} observed no significant changes in peak torque and rate of torque development in the hip extensors in 29 healthy male subjects after four weeks of a static stretching protocol for the hip extensors.

\textit{Strength.}

Flexibility protocols have been shown to increase strength in both upper body and lower body exercises. Wilson et al.\textsuperscript{26} studied the effects of static stretching coupled with auxiliary strength exercises designed to increase upper body joint range of motion (ROM) in 18 male powerlifters. A 10-15 minute session performed two days per week for eight weeks resulted in an increase in rebound bench press performance (5.4%) for the stretching group compared to the control group. The rebound bench press was a traditional bench press performed without a pause between the eccentric and concentric phases of movement. An increase was also seen in the experimental group in rate of work production during the first 220 ms of the concentric phase of the rebound bench press lift, indicating an improvement in rate of force development. A non-statistically significant increase was seen in purely concentric bench press performance (4.5%) for the stretching group. Kokkonen et al.\textsuperscript{13} measured the effectiveness of an eight-week static stretching protocol on knee extension and flexion 1RM, and leg press 1RM. Thirty-two college
students were divided into either a standard progressive resistance training (WT) group or a group performing the same progressive resistance training combined with static stretching exercises (WT + ST). The WT + ST groups exhibited significantly higher increases in knee extension 1RM (26.8% vs. 13.7%) and leg press 1RM (30.8% vs. 8.8%) compared to the WT group. The WT + ST group exhibited an increase in knee flexion 1RM (16.2%), which was significant over the pre-score, but was not significantly higher than the knee flexion 1RM of the WT group. In a previous study, Kokkonen et al.\textsuperscript{12} showed significant increases in knee flexion (15.3%) and extension (32.4%) 1RM for the stretching group compared to the control group.

\textit{Power.}

Hunter et al.\textsuperscript{10} looked at the effects of flexibility training on vertical jump performance. 50 subjects from various sporting backgrounds participated in a ten-week stretching program, involving a combination of both static and PNF stretching methods. Four study groups were divided into a power and stretch training group (PS), power only group (P), stretch only group (S), and a control group (C). A significant increase was seen in vertical jump height of the S group versus the C group (1.3 +/- 1.5 cm), and of the PS group versus the P group (4.9 +/- 2.2 cm). No change was seen in reversible muscle actions, as indicated by unchanged drop jump ground contact times. Similarly, Yuktasir et al.\textsuperscript{30} found no change in drop jump ground contact times after six weeks of static and PNF stretching methods in 28 male university students. The findings by Hunter, et al. showing an increase in vertical jump height were contradicted by those of Bazett-Jones et al.\textsuperscript{1} showing no increase in vertical jump height after six weeks of hamstring flexibility training in 21 Division III women’s track and field athletes. Kokkonen et al.\textsuperscript{12} measured the effect of a ten-week static stretching protocol on forty recreationally active college students. The students were divided into a stretching group and a control group. Standing long
jump distance and vertical jump height increased significantly in the stretching group by 2.3% and 6.7%, respectively.

**Acceleration/Speed.**

There is mixed research showing the effects of increased flexibility on acceleration and speed. As well as observing increases in lower body power with stretch training, Kokkonen et al.\textsuperscript{12} saw improvements in 20-m sprint time. 20-m sprint time significantly decreased (-1.3%) in the stretching group compared to the control group. Conversely, in addition to showing no increases in vertical jump height after six weeks of hamstring flexibility training, Bazett-Jones et al.\textsuperscript{1} also showed no improvement in 55-m sprint times.

**Endurance.**

Kokkonen et al.\textsuperscript{12} saw improvements in muscular endurance (defined at repetitions to failure of a 60% of 1RM load). Knee flexion and extension endurance increased significantly by 30.4% and 28.5%, respectively in the stretch trained grouped, whereas there was no change in the control.

Nelson et. al.\textsuperscript{19} touched on the effects of chronic static stretching and endurance performance in terms of aerobic capacity. They observed the changes in running economy in 32 college-aged runners following a ten-week calf and thigh stretch training protocol. There were no significant differences in pre and post running economy (determined by a ten-minute submaximal treadmill run), indicating that chronic static stretching does not affect endurance performance in terms of running economy.

**Dynamic stretching**

The majority of research on dynamic stretching has focused on its acute effects on performance, most of which has shown that dynamic stretching is beneficial for sports
performance. However, only Herman et. al. has studied the chronic effects of dynamic stretching on performance measures. A four-week dynamic stretching protocol was implemented on Division I wrestlers and the results showed significant increases in several performance measures, including: quadriceps peak torque (11%), broad jump height (4%), medicine ball throwing distance (4%), timed sit-ups number (11%), push-ups (3%), 300-yard shuttle run (2%) and 600-meter run (2.4%). These performance gains were highlighted by performance decrements in a concurrent static stretching group.

DISCUSSION

Static stretching

Increases in isokinetic torque production due to static stretching are more pronounced in the eccentric phase versus concentric muscle actions. In addition to increased joint ROM, improving the ability of the hip and knee flexors and extensors to eccentrically absorb higher levels of force by improving flexibility could contribute to a decrease in injury rate during landing.

Although increasing flexibility is an effective method for increasing muscle performance under select isokinetic conditions, it is still unclear whether strength in closed-chain movements is improved from static stretching programs. Of the studies observed for this paper, only Kokkonen et al. showed an increase in closed-chain force production as a result of stretching and resistance training, documenting an increase in leg press 1RM performance. Further research must be conducted to determine if increased flexibility improves force production in closed chain movements.
From the research studies observed in the scope of this paper, some generalities were seen between study length and results seen. Of the studies observed, those lasting eight weeks or longer showed performance increases, while those lasting less than six weeks tended to show little to no change. This could be due to an adaptation period necessary to see performance improvements from increased flexibility. While studies have shown joint range of motion improvements with as little as four weeks of flexibility training,\textsuperscript{4, 16} results from the current literature suggest a protocol length of eight weeks or more to observe significant performance increases from static stretching protocols. Of the studies utilized in this paper, only Worrell, et al.\textsuperscript{28} saw performance increases utilizing a static stretching protocol lasting less than eight weeks.

One study that observed no change in power performance, Bazett-Jones et al.\textsuperscript{1}, included only hamstring flexibility in the study’s stretching protocol. The hamstrings are not the only muscle group responsible for power production during acceleration and sprinting, which leads us to believe that improving total lower body flexibility is a much better method for improving sprint performance. When a complete lower body stretching protocol is followed, similar to the protocol prescribed by Kokkonen et al.\textsuperscript{12}, improved power and acceleration measures are more likely.

**Dynamic stretching**

Dynamic stretching has been gaining more popularity as studies have been showing acute performance decrements with static stretching. In recent years, more and more research has focused on the effects of dynamic stretching on performance. However, this focus has mainly been on its acute effects, showing that dynamic stretching positively influences various measures
of performance. Herman et al.’s study is the first to show that chronic dynamic stretching positively impacts measures of performance.

It would stand to reason that even if chronic dynamic stretching does not produce additional benefits to those produced acutely, we would still see chronic performance increases on par with those seen acutely. Thus, if most of the research points towards dynamic stretching having acute positive influences on performance, we would see those same results in long term studies. However, more research must be conducted to prove or disprove this theory.

The purpose of a warm-up before activity is to increase muscle blood flow and temperature, transmission rate of nerve impulses, muscle and tendon suppleness, and decrease muscle viscosity, intramuscular resistance, and activation energy for cellular reactions. Dynamic stretching helps facilitate many of the above mentioned actions, which may be why it is effective acutely. However it is difficult to ascertain mechanisms behind increased performance following chronic dynamic stretching. This is again mainly due to the lack of research showing that dynamic stretching indeed leads to performance enhancements.

CONCLUSION

Studies suggest that chronic static stretching improves flexibility, although the relationship between increasing joint range of motion prior to exercise and injury prevention remains unclear. But, it is clear that static stretching acutely decreases muscular strength, speed, power, and endurance in subsequent exercise bouts. That said however, there is substantial literature that suggests that chronic static stretching routines can improve performance measures of strength, speed/acceleration and power (Table 1).
One of the main adaptations to chronic static stretching from an injury prevention standpoint may be the ability of the quadriceps and hamstrings to absorb significantly higher eccentric loads. While many studies have validated the use of flexibility protocols to improve strength and isokinetic torque in open chain situations, more research must be performed to determine the value of such protocols to increase strength in closed chain movements. From the current literature, it appears eight weeks is the minimum program length necessary to see adaptations resulting in performance improvements from chronic static stretching. It can be concluded from the literature that stretching protocols incorporating exercises for the flexors and extensors of both the knee and hip joints are necessary to observe improvements in lower body speed/acceleration, power, and strength.

Dynamic stretching prior to exercise has been shown to increase performance in the short-term. But, more research must be performed to confirm its value to long-term performance gains.

Overall, the research indicates that athletes, trainers and coaches may continue employing static and dynamic stretching exercises in their training programs, since such protocols seem to produce either positive or no changes to performance. As of yet, no studies have shown any decreases in performance with chronic stretching programs. Static stretching, however, should be included as a post-exercise activity, so as not to decrease performance acutely.
REFERENCES


