

The unknown truth about stretching.

Does pre-exercise stretching reduce the risk of injury?

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Abstract

Introduction: Although there is a lack of scientific evidence, it is still widely believed that pre-exercise stretching is a quick and effective way to reduce the risk of injury. To determine if stretching is an effective means to reduce the risk of injury, we first have to look what the effects of stretching are at muscle stiffness, compliance and how long we need to hold the stretch for.

The main question of this study is: Is pre-exercise stretching an effective means to reduce the risk of injury?

The subquestions are:

1. Which stretch holding time is needed to increase ROM?
2. Is muscle stiffness a risk factor for muscle damage?
3. Does stretching increase muscle compliance?

Methods: The electronic databases used are: Pubmed and Omega. There has been searched using the following terms and combinations of the terms: stretching, pre-exercise, injury, prevention, muscle and duration. Inclusion criteria were: articles written in 2000 or later or the most recent known research, stretching had to be done pre-exercise, the focus of the research had to be about stretching as a means to prevent injury. The methodological quality of the articles have been assessed using a Cochrane checklist

Results: Stretch holding time: Roberts, Wilson.⁴ found that a stretch program with only a 5 seconds stretch duration is sufficient to increase ROM. They have stretched 3 times a week for 5 weeks. The total stretch time was 45 seconds.

Muscle stiffness: Malachy et al.⁵ have found that subjects with stiffer hamstring muscles experienced greater strength loss, more pain and greater muscle tenderness.

Witvrouw et al.⁶ found a significant difference in ROM between the injured and uninjured players for the quadriceps and hamstring muscle. There was no difference in ROM of the adductor and gastrocnemius

Compliance: Mahieu et al.⁷ found that after 6 weeks of stretching all groups had a significantly improved ankle dorsiflexion, even the control group.

The passive resistive torque only decreased significantly for the static stretch group and not for the ballistic and control group.

Cornwell et al.⁸ found stretching to decrease active stiffness, but no change was found on the static jump height. Countermovement jump was significantly lower and ROM increased significantly.

Injury prevention: Brooks et al.⁹ found inconclusive results and Pope et al.¹⁰ found no significant effect of stretching under 1538 army recruits

Conclusion: Stretch holding time: A stretch program with only a 5 seconds stretch duration is sufficient to increase ROM.

Muscle stiffness: Based on the results in this article we conclude that muscle stiffness is a risk factor for muscle damage

Compliance: At this moment there isn't enough evidence to support stretching as an effective means to improve the compliance of a muscle

Injury: Based on these results there isn't enough evidence to support stretching as a means to prevent injury.

Recommendations: More research is needed with large populations and also combinations of stretching methods.

Discussion: Most of the results on which this paper is based are from small populations. Research with larger populations is needed. All of the evidence is for lower limb injuries. No research is done for the upper extremities. Maybe the influence of muscle stiffness on injury is different in individual muscle groups. This would mean that stretching only particular muscle groups is effective. The compliance gained by stretching might be overshadowed by the influence of other risk factors like age and overall fitness, and therefore no reduction in injury is found.

Malachy et al.⁵ and Cornwell et al.⁸ had a short follow up. It is unknown if the examiner was blind for the allocation with the studies of Malachy et al.⁵, Mahieu et al.⁷ and Cornwell et al.⁸

Introduction

A healthy lifestyle is getting more and more important in our society. Sport plays an important role in maintaining that healthy lifestyle. With sport comes injuries and the means to prevent it.

Although there is a lack of scientific evidence, it is still widely believed that pre-exercise stretching is a quick and effective way to achieve that goal.¹ It is important to understand the theory behind stretching. How can stretching reduce the risk of injury?

Most injuries occur when the musculotendinous unit is unable to fully absorb all the energy. The absorbance capability depends on both the active contractile unit (muscle) and the passive component (tendon). In a compliant system with the contractile component active, more energy can be absorbed by the tendon tissue. In case of a low compliance, forces will be transferred to the contractile component and little energy will be absorbed in the tendon. As tendon stiffness increases, the greater the forces are generated within the muscle.² Based on this, the purpose of stretching should be to increase the compliance of the tendon.

If you keep in mind that stretching a muscle to 20% of its resting length can produce damage within the muscle², an increase of stretch tolerance might only lead to a higher injury risk.

Compliance is mostly measured by passive range of motion (ROM). It has been stated that observed increase of range of motion isn't due to an increase in tissue compliance but rather of an increased stretch tolerance (reduced pain)³.

There are a lot of conflicting theories behind stretching which makes it difficult to determine its effect. To determine if stretching is an effective means to reduce the risk of injury we first have to look what the effects of stretching are at muscle stiffness, compliance and how long we need to hold the stretch for.

The main question of this study is:

1. Is pre-exercise stretching an effective means to reduce the risk of injury?

The sub questions are:

1. Which stretch holding time is needed to increase ROM?
2. Is muscle stiffness a risk factor for muscle damage?
3. Does stretching increase muscle compliance?

In this article injury is defined as: any injury that prevents a subject to resume his/her full duties.

When spoken about stretching, it is about static or ballistic stretching.

Static stretching is lengthening a muscle until you feel a stretch sensation or just before the feeling of discomfort. Then you hold that muscle length for a certain amount of time.

Ballistic stretching is the same as static stretching except that you don't hold the muscle length but make an alternating movement in which the muscle length decreases and increases up to the stretching sensation or before the feeling of discomfort.

Methods

The electronic databases used are: Pubmed and Omega. There has been searched using the following terms and combinations of the terms: stretching, pre-exercise, injury, prevention, muscle, duration. Inclusion criteria were: articles written in 2000 or later or the most recent known research, stretching had to be done pre-exercise, the focus of the research had to be about stretching as a means to prevent injury.

The focus of the search was to find as many randomized control trials (RCT) as they are the golden standard of evidence. As there was a lack of adequate RCT, trials and controlled trials are included in the study as well. There aren't many recent studies on stretching regarding injury prevention. Most studies are done in the 80's and 90's. Most of the recent research is about stretching as a means to improving performance. There were only four RCT's that met the inclusion criteria, and only two of them examined if stretching prevented injury. These RCT's will be assessed in this article. They are: Brooks(2006), Mahieu(2006), Malachy(1999) and Pope(1999)

The methodological quality of the articles have been assessed using the Cochrane checklist for systematic review, cohort study RCT.

Results

Stretch holding time

There is no standard for the duration of the stretch needed to achieve an increase in ROM.

But how important is the stretch duration?

Robert and Wilson⁴ investigated this on a group of 24 university sport club members. Although the research is from 1999, it is the most recent in its topic and has a high methodological quality. They were randomly assigned into 3 different groups. N=8 for each group. The first group would stretch 3 times a week for a duration of 5 weeks. They would stretch 9 times and hold the stretch for 5 seconds. The second group would stretch 3 times and hold their stretch for 15 seconds. This way both groups

would stretch for a total of 45 seconds. The third group was the control group and did not stretch. Active and passive ROM was determined before and after the 5 week program for hip flexion, knee flexion and knee extension.

There was no significant difference in ROM for the control group compared to the previous measurements.

Both stretch groups did show a significant increase compared to the control group. There was no significant difference between the 5 and 15 seconds stretch group for the passive ROM. The 15 seconds stretch group showed significantly greater improvements in active ROM compared to the 5 seconds stretch group.

Muscle stiffness

The whole idea behind stretching is that it makes the musculotendinous unit more compliant.

Muscle stiffness is a big factor in muscle compliance.

But is there any prove that compliance has anything to do with muscle damage. Damage is usually described according to various symptoms: strength loss, pain with activity and muscle tenderness.⁵

Based on this Malachy et. al.⁵ have held a trial with a good methodological quality under 20 participants which they divided into three groups, based on there muscle compliance. Compliance N=7, Normal N=6, Stiff N=7. They wanted to see if muscle stiffness, which has a big influence on compliance, had an influence on muscle damage. After performing eccentric hamstring muscle actions they measured for three consecutive days the maximum isometric strength, pain and muscle tenderness. The eccentric actions are performed using a dynamometer. The subject is seated in an upright position with hip at 90° flexion and the knee at 45° flexion. The dynamometer would move from 90° to 0° of knee flexion at 150° per second. The subjects had to contract the flexor muscle group with sufficient intensity to reach a visually displayed target strength equal to 60% isometric strength. The isometric strength is measured in the same position, except the dynamometer stays stationary. The subjects then had to maximally contract the knee flexors and the peak torque was recorded. The pain was recorded using a scale from 0(no discomfort) to 10(walking with a limb).

Muscle tenderness was assessed by pressing a 18mm probe into the hamstring muscle. The subjects reported any discomfort at which the force at that point was recorded.

They concluded that subjects with stiffer hamstring muscles experienced greater strength loss, more pain and greater muscle tenderness.

Witvrouw et al.⁶ have held a prospective study with a high methodological quality under Belgian soccer players. They were interested in first

incidence muscle injuries. Of the 146 subjects included in the study, ROM was recorded for the hamstrings, quadriceps, adductor and gastrocnemius on both legs. ROM is used as a means to measure the stiffness of a muscle. The time spent in training and games was documented. Of the 146 subjects 67 subjects sustained an injury during the study. There was no significant difference between the time spent in training and games, between the injured and uninjured players. There was found a significant difference in ROM between the injured and uninjured players for the quadriceps and hamstring muscle. There was no difference in ROM of the adductor and gastrocnemius.

Compliance

Passive muscle

It is important to note that muscle compliance at rest and during activity is unrelated.³

First we look at the compliance at rest(passive). There was only one research that fell within the inclusion criteria and had a good methodological quality. Mahieu et al.⁷ had in total 81 volunteers which were divided into three groups. Static stretching N=31, Ballistic stretching N=21 and Control N=29.

Both the static and ballistic group performed a stretching program of the calf muscle for six weeks. The stretching program consisted of five stretches with each leg. The holding time of the stretch was 20 seconds with a 20 seconds rest in between. Before and after the six weeks, measurements were taken for ankle dorsiflexion and passive resistive torque.

The passive resistive torque is measured by moving the ankle joint passively from 20° plantar flexion to 10°dorsiflexion at 5° per second using a dynamometer. The force required to move the ankle was recorded.

After six weeks all groups had a significantly improved ankle dorsiflexion ROM, even the control group who didn't stretch at all.

The passive resistive torque only decreased significantly for the static stretch group.

Active muscle

Cornwell et al.⁸ have looked at the active muscle. They held a trial with medium methodological quality under ten male participants. Before and after a bout of static stretching they measured: Active stiffness of the triceps surae muscle-tendon complex, active ROM, static jump height and countermovement jump height.

We look at static and countermovement jump height not to see if stretching can improve

performance, but because the performance can say something about the compliance.

A stiff musculotendinous unit allows the force generated by the contractile component to be transmitted to the skeletal system much more effectively than a compliant unit,^{2,8} thus an increase of muscle compliance should show an decrease in static jump height.

The muscle can also generate energy the same way a spring does. The muscle is stretched before shortening, stretch-shortening cycle(SSC), like in the countermovement jump. With an SSC, a more compliant musculotendinous unit allows for the effective storage and release of series elastic energy. An increase of muscle compliance should show an increase of performance on the countermovement jump.² It must be mentioned that there might be a ideal level of muscle compliance for SSC beyond which performance will decrease.^{2,8}

The stretch protocol consisted of two static passive stretching exercises which were performed three times, each for a period of 30 seconds. Post stretching no significant change was found for the static jump. Countermovement jump height was significantly lower, active stiffness showed a small but significant decrease and the ROM increased significantly.

Although the active stiffness decreased, the static jump was unchanged. This might indicate that the decrease in stiffness was not enough to change the ability to effectively transfer the forces generated. The countermovement jump showed a decrease in performance indicating that the compliance might be beyond the optimal level.

Injury prevention

After looking at the theoretical aspects of stretching as injury prevention and the evidence for it, we will now look if there is any hard proof that stretching works to prevent injuries.

Brooks et al⁹ have held a study with high methodological quality under professional rugby players. In total 546 players took part. Medical personnel at each club reported the occurrence of all hamstring injuries sustained together with injury details (excluding lacerations, abrasions and haematomas). The number of training sessions and volume of each training activity were also recorded. The players were divided in three groups. Strengthening group N=148, strengthening and stretching group N=144 and strengthening stretching and Nordic strengthening group N=200. There was no significant difference in injury severity or the incidence of match injuries between the three groups.

The incidence of training injuries was significant lower in the stretching group and Nordic strengthening group than the strengthening group. As there is a discrepancy between the training and match results, the injury reduction found might be caused by other factors than stretching.

Pope et al. held an RCT with high methodological quality under 1538 army recruits.¹⁰ They were divided into a stretch and control group.

The stretch group was given a stretch program for the gastrocnemius, soleus, hamstring, quadriceps, hip adductor and hip flexor muscle groups. They stretched before all physical activities. The stretches were held for 20 seconds. The stretches were interspersed with a 4 minute warm-up. The control group only performed a warm-up and did not stretch.

Once a subject had presented an injury his “survival time” was considered terminated. Thus only training days before injury were taken into the final analysis.

In total 333 lower-limb injuries were recorded: 175 in the control group and 158 in the stretch group. No significant effect of stretching was found.

Conclusion

Stretch holding time

There is no standard for the duration of the stretch needed to achieve an increase in ROM

That's why Robert and Wilson⁴ investigated this on a group of 24 university sport club members.

There was no significant difference between the 5 and 15 seconds stretch group for the passive ROM. The 15 seconds stretch group showed significantly greater improvements in active ROM compared to the 5 seconds stretch group.

In conclusion one can say that even a stretch program with only a 5 seconds stretch duration is sufficient to increase ROM, but the effect on active ROM is greater with a longer stretch holding time.

Muscle stiffness

Malachy⁵ have found that subjects with stiffer hamstring muscles experienced greater strength loss, more pain and greater muscle tenderness after performing eccentric hamstring muscle actions.

Witvrouw et al.⁶ found a significant difference in ROM between the injured and uninjured players for the quadriceps and hamstring muscle. There was no difference in ROM of the adductor and gastrocnemius

Based on the results in this article we conclude that muscle stiffness is a risk factor for muscle damage. But we must keep in mind that it might not be for all muscle groups.

Compliance

Mahieu et al.⁷ have looked at the compliance of the muscle with the muscle at rest (passive). They found that after 6 weeks of stretching all groups had a significantly improved ankle dorsiflexion ROM, even the control group who didn't stretch at all. The passive resistive torque only decreased significantly for the static stretch group and not for the ballistic and control group.

Cornwell et al.⁸ have looked at the active muscle. They found stretching to decrease the active stiffness, but there was no change on the static jump height. This might indicate that the decrease in stiffness was not enough to change the ability to effectively transfer the forces generated. This might also indicate that stretching isn't effective enough to influence the forces generated within the muscle.

At this moment there isn't enough evidence to support stretching as an effective means to improve the compliance of a muscle

Injury prevention

There are only two large RCT's that directly look if stretching prevents injury. Brooks et al.⁹ have found a decrease in training injuries after stretching but not a decrease in match injuries. Thus making it impossible to come to a conclusion based upon this research.

Pope et al.¹⁰ have found no significant change in injuries after stretching.

Based on these results there isn't enough evidence to support stretching as a means to prevent injury. Only Brooks et al.⁹ found a significant difference in training injuries with the stretching group. But there were no significant differences in match injuries, so the difference might have been due to other factors like age, fatigue and overall fitness.

Recommendations

When we look at the theory of stretching, the evidence for stretching to lower the compliance is inconclusive and more research should be done in this field. Most of the stretches used in the researches is a static stretch. More research is needed to see if a combination of ballistic and static stretching shows better results for improving compliance.

Although the population of Pope et al. is large it is impossible to base a definitive conclusion on one trial. More research is needed with large populations and also combination of stretching methods.

Discussion

Most of the results on which this paper is based are from small populations. Research with larger populations is needed to be able to make a decisive conclusion.

There are little recent RCT's regarding these subjects, thus making the evidence found weak. All of the evidence is for lower limb injuries. No research is done for the upper extremities and most is concentrated on the hamstrings.

Witvrouw et al.² found that there was a difference in muscle stiffness between the injured and uninjured group for hamstring and quadriceps muscle groups, but no difference was found for the adductor and gastrocnemius. It must be said that these muscles also recorded the least injuries, thus ending up with a small population. It might be too small to make a decisive conclusion for these muscle groups.

Maybe the influence of muscle stiffness on injury is different in individual muscle groups. This would mean that stretching only particular muscle groups is effective.

The research of Malachy et al.⁵ has a short follow up and it is unknown if the examiner was blind for the allocation.

With the research of Mahieu et al.⁷ it is unknown if the examiner was blind for the allocation.

The study of Cornwell et al.⁸ had a short follow up and it is unknown if the examiner was blind for the allocation.

Based upon the fact that there is some evidence that stretching improves muscle compliance, but no significant reduction in injuries is found, it is the opinion of the author that muscle compliance might be a small risk factor compared to other risk factors like age, fatigue and overall fitness.¹⁰

The compliance gained by stretching might be overshadowed by the influence of other risk factors and therefore no reduction in injury is found. To effectively reduce the risk of injury, the time and energy spent in stretching might be better used to reduce injury risk by influencing other risk factors such as overall fitness.

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