Scientific Basis of Active Isolated Stretching: A Review

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ABSTRACT

Kukkonen PT. Scientific Basis of Active Isolated Stretching: A Review. JEPonline 2019(22):58-70. Aaron L. Mattes made the observation that stretching along the line of stress of the muscle and relaxation of the muscle in each repetition of stretch would diminish the resistance to stretching. Based on this observation, the purpose of this review will be to demonstrate that Active Isolated Stretching (AIS) is performed with less torque than static stretches, but nonetheless increases joint range of movement (ROM) of the hamstring muscles more so than static stretches. By searching the studies on static stretching, it was possible to find 14 articles that reported mean maximal torques of hamstring and calf muscles. These measurements were compared to optimal - maximal torque of AIS. The result is that the AIS stretches are performed with less torque than static stretches. This inference should be confirmed by experimental studies. It was also possible to find 4 articles that reported AIS increasing ROM of the hamstring muscles more or at least the same amount as static stretching. Mattes finding, that stretching along the line of stress of the muscle and relaxation of muscle in each repetition is the main mechanism of action of AIS. The findings of this review would be the basic theory of AIS. The main mechanism of AIS could renew the stretching techniques. Hence, this review should have very positive effect on exercise physiology.

Key Words: Flexibility, Musculoskeletal, Relaxation
INTRODUCTION

Few exercise physiology research studies have been published on Active Isolated Stretching (AIS). The mechanism of action of AIS has not been thoroughly investigated. On some other stretching techniques, Weppeler and Magnusson (31) published in 2010 a review of the mechanisms of action of the techniques. This development was made possible by evaluating the biomechanical properties of stretching. When including the use of tension in muscle length evaluation, studies on stretching were able to construct torque-angle curves before and after stretching. Measuring maximal torques used in most stretching techniques became possible.

Mattes (20-23) was developing AIS when he was directing Kinesiotherapy Clinics at the University of Illinois in 1972-1976 and at the University of Toledo in 1976-1979. He is an expert in massage therapy and kinesiotherapy. As an athlete himself, he was frustrated when he suffered an injury and there were only ineffective rehabilitation methods available. By trying a great number of positions and stretches, he finally found a stretching technique that seemed to function properly. Mattes found in his many trials the combination of stretching along the stress line of the muscle and relaxation of the muscle to be stretched in each of the repetitions. Both were needed in order to diminish the resistance to stretching of a muscle.

If the resistance to stretching is smaller along stress lines, why have the numerous researchers not discovered, even by accident, to use stress line of muscle when investigating static stretching? If the muscle is not relaxed, stretching along the stress line does not diminish the resistance. Relaxation could be a precondition for smaller resistance.

According to Mattes (21), AIS is performed very lightly, with less than 1 lb (4.5 Nm) pressure. The optimum pressure is only 6 to 8 ounces or 1.7 to 2.3 Nm (30). Stretch lasts 1 to 2 sec and there are 8 to 10 reps of stretch. The muscle to be stretched is relaxed by contracting the antagonist muscle when moving body part actively from the starting position to the stretching position.

Mattes would have been developing AIS gradually and finally in books of 2000 (20,23) and 2012 (21) he concluded that the laws of Sherrington and Wolff formed the scientific basis of AIS (20,21). But, since this was not convincing evidence of the scientific value of AIS, he tried to get medical researchers involved in developing AIS. According to “Massage Magazine” (internet), Mattes and his associate, Jeffrey Haggquist DO, arranged in Washington D.C. in June of 2008 from the 10th to the 14th a seminar, where AIS and medical experts together developed AIS applications. The aim was also to encourage researchers to start researching AIS. In 2009, Mattes was working with NIH (National Institutes of Health) to design pilot studies to demonstrate the value of AIS to the scientific community (30).

These attempts did not succeed because the researchers at that time did not have the tools to show the value of AIS. Before the year 2010 only a few research teams were
able to use torque-angle curves and maximal torques in stretching and had devices to measure them. The main interest of these research teams was in sensory theory of static stretch and not in AIS. Since Weppler and Magnusson’s review article (31) in 2010, torque-angle curves and maximal torques in stretching have been better known.

SOME IDEAS OF AARON L. MATTES

Relaxation
Mattes (21) states that only relaxed myofascial structures can be optimally stretched. Relaxation is based on Sherrington’s law of reciprocal inhibition. Contraction of an agonist muscle on one side of a joint sends a signal to the opposite side muscle to relax. The positions and movements of AIS are designed so that the movement of stretching a person from a starting position to a stretching position relaxes the muscle or muscles automatically. Relaxation is augmented by exhaling of the person when moving through the stretching position. After each stretch, the area being stretched should always be returned to the starting position before the next repetition. There should be 8 to 10 reps for each stretch.

Stretching Along the Lines of Stress in the Body and Muscle
Stretching should be directed along the stress line for each muscle. Mattes derived this principle from Wolff’s law that originally concerns bones. Also, the sheets of fascia are laid down along the lines of stress within the body and they adhere to proper anatomical positioning. The conclusion by Mattes (21) is supported by Myers (26) who demonstrated how long collagen molecules of muscle orient themselves along the lines of tension of the muscle. Mattes (21) expressed the same anatomical feature on macro level with the collagen fibres laid down along the lines of stress within the body.

Mattes studied origin, insertion, and action of each muscle to decide the optimal direction it should be stretched. Parts of some muscles have their own stress lines and optimal stretches. Stretching along the line of stress of the muscle and relaxation of muscle minimizes tension and friction among fascial sheets so that they start to move, although stretch is done with minimal pressure or torque. In repetitions of the stretch, this works to break down adhesions and scar tissue formations that have been caused by inflammation resulting from soft tissue traumas. Breaking down adhesions mitigates or removes muscular pain. Stretches also realign collagen fibres and reduce muscle spasms.

Repetitive Muscle Contractions and Breathing in Their Rhythm
In order to facilitate relaxation, one should exhale when moving from starting position to stretching position and inhale when returning back to starting position. Breathing and repetitive muscle contractions deliver greater amounts of circulating blood, oxygen, and nutrition to the muscles. They also stimulate circulation and drainage of lymph, which helps to eliminate metabolic wastes, such as lactic acid. Joint angle expands in each repetition. Combining flexibility and strength training systems is one feature of AIS. Muscle opposite to the one being stretched is being strengthened at the same time. This takes place in each repetition. Movement increases strength of muscles in good
balance on both sides of the body, as well on both sides of the lower and upper extremities when all major muscles are stretched systematically.

**COMPARISON OF THE MAXIMAL TORQUES IN AIS AND STATIC STRETCHING**

Because no studies have been published on the mechanisms of action of AIS in peer-reviewed journals, a Master of Science thesis in kinesiology at the Brock University in Ontario, Canada, has been used (for one part) in the comparison. The title of the study is “Active Isolated Stretching: An Investigation of the Mechanical Mechanisms” by Longo (14). The experimental part of the study provides some valuable hints on the mechanisms of action of AIS. The subjects in the study were university students (8 females and 2 males) with tight hamstrings. During 6 wks they made daily 2 series of knee (right side) extension AIS stretches with 10 reps with a 30-sec interval between series. The stretches were done with less than 1 lb force and the last (10th) repetition was taken so far that the subject felt a light irritation. The left leg was a control. Before and after the 6 wks of stretching, knee extension ROM and resistance to stretch were measured with a dynamometer (Biodex System 3) for both legs (with gravity correction). The Delsys Bagnoli-4EMG-system was used to monitor electric activity of the vastus lateralis and hamstring muscle group with electrodes placed on the muscles.

Main result of Longo`s experiment was that the mechanism of action of AIS is not mechanical. Values measured before and after stretching are approximately on the same line (Figure 1). Knee extension ROM increased significantly by 15° and there was an indication that long-term AIS (6 wks in the experiment) would be efficient in increasing ROM. Longo also made the conclusion that EMG measurements show that the hamstring muscles were significantly less active than the vastus lateralis muscle and that reciprocal inhibition was occurring and hamstrings were relaxed (14 p. 67).

![Figure 1](image_url) Torque-angle curve for 1 subject from Longo`s study

Figure 1 is a modified figure from Longo`s study on knee extension AIS-stretching (14). The person was applying only 30 Nm torque to do the final repetition of knee extension AIS stretch. Unfortunately, mean maximal torque after stretching for all the 10 subjects is not available. According to Mattes (30), the optimal AIS stretch is very light, about 2 Nm and with 10 reps at a torque of 20 Nm. The upper limit for the use of force is less than 1 lb (or 4.5 Nm) torque. Therefore, for AIS optimal - maximal torque range is 20 to 45 Nm for comparison with static stretching.
Last column of Table 1 gives a list of mean maximal torques used in static stretches of hamstring and calf muscles. The first 5 studies are found as references in Weppler and Magnusson’s review article (30). The rest of the 9 studies are found from a review by Freitas et al. (6) published in 2018. The review had the restriction in searching of articles that only stretching interventions of more than 2 wks duration were accepted.

Table 1. A List of Mean Maximal Torques used in Static Stretches.

<table>
<thead>
<tr>
<th>Studies of Static Stretching</th>
<th>Stretching Exercise weeks</th>
<th>Increase in ROM degrees</th>
<th>Mean Maximal Torque Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hamstring Muscles</strong></td>
<td></td>
<td></td>
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<tr>
<td>Magnusson et al. (16)</td>
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<td>75</td>
</tr>
<tr>
<td>Reid and McNair (28)</td>
<td>6</td>
<td>10</td>
<td>114</td>
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<tr>
<td>Ylinen et al. (32)</td>
<td>4</td>
<td>17</td>
<td>105</td>
</tr>
<tr>
<td>Ben and Harvey (2)</td>
<td>4</td>
<td>10</td>
<td>65</td>
</tr>
<tr>
<td>Folpp et al. (5)</td>
<td>4</td>
<td>9</td>
<td>67</td>
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<tr>
<td>Magnusson et al. (17)</td>
<td>3</td>
<td>10</td>
<td>52</td>
</tr>
<tr>
<td>Gajdosik (7)</td>
<td>3</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>Law et al. (12)</td>
<td>3</td>
<td>10</td>
<td>44</td>
</tr>
<tr>
<td>Chan et al. (4)</td>
<td>4</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>LaRoche &amp; Connolly (11)</td>
<td>4</td>
<td>9</td>
<td>149</td>
</tr>
<tr>
<td><strong>Calf Muscles</strong></td>
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<td></td>
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<tr>
<td>Gajdosik et al. (8)</td>
<td>8</td>
<td>5</td>
<td>122</td>
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<tr>
<td>Guissard &amp; Duchateau (10)</td>
<td>6</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>Gajdosik et al. (9)</td>
<td>6</td>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td>Blazevich et al. (3)</td>
<td>3</td>
<td>8</td>
<td>110</td>
</tr>
</tbody>
</table>

Figure 2  AIS is performed with less torque than static stretching

Static stretching studies from table 1:
Mean maximal torque values ( I ) and their range ( △ )

AIS: Optimal – maximal torque range ( ▲ )

Torque, Nm
According to the studies in Table 1, mean maximal torques of static stretching range between 26 and 149 Nm. For AIS the optimal-maximal range of torque would be 20 to 45 Nm. Although there is slight overlap in the ranges in Figure 2, one can infer that with a quite high probability Figure 2 demonstrates that AIS is performed with less torque than static stretch. The inference is reasonable, and it can be confirmed by studies whereby the subjects are performing AIS and static stretches and torque-angle relationships are measured as well as mean maximal torques after stretching. The studies should be made both for hamstring muscles and calf muscles using available measurement devices.

Table 2. Gender of Subjects has an Influence on Mean Maximal Torque.

<table>
<thead>
<tr>
<th>Studies of Static Stretching</th>
<th>Mean Maximal Torque Nm</th>
<th>Subjects in Stretch Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Males</td>
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<tr>
<td>Hamstring Muscles</td>
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</tr>
</tbody>
</table>

Gender and age seem to influence the results of stretching, mainly because females are more flexible than males and because flexibility is decreased after a certain age. In the studies, males and aging subjects seem to use greater maximum torque than females and younger persons. In the LaRoche and Connolly (11) study, the average age of the 9 participating men was 31 yrs of age, and some of them may have been over 60 yrs of age. Therefore, they are less flexible and the mean maximal torque is high, 149 Nm. The other high mean maximal torque of 122 Nm is in the Gajdosik et al. (8) study on calf muscles of older women with an average age of 73 yrs. A very different story is reported...
in Chan et al. (4) where the subjects are young women and men with an age range of 18 to 25 yrs and mean maximal torque is only 28 Nm.

THE MECHANISM OF ACTION OF AIS

The main mechanism of action of AIS would be stretching along the lines of stress in the muscle and relaxation of the muscle to be stretched in each of the 8 to 10 reps. Mattes and several AIS experts have a 40-yr experience in applying AIS in sport, sport injuries, and various musculoskeletal problems. This means that there is a large experience-based knowledge behind the other suggested mechanisms of action of AIS.

As a consequence of the main mechanism, friction among fascial sheets is reduced and they start to move. This movement among fascial sheets during repetitions breaks down adhesions and scar tissue formations of muscles. The breaking down of adhesions mitigates or removes muscular pain. This is the first suggested mechanism, which should be confirmed by more research in this area.

Breathing and repetitive muscle contractions accelerate circulation of blood and lymph. This delivers oxygen and nutrition to muscles and reduces metabolic wastes like lactic acid. The repetitive muscle contractions also work as strength training. These would be the second suggested mechanism. Again, more research studies is essential to confirm the suggested mechanisms. There might be other effects of AIS, such as stretching reducing muscle spasms and realign collagen fibers as Mattes has suggested. Therefore, the two suggested mechanisms may be just the beginning of the list of possible mechanisms of AIS action.

ONE ASSUMPTION OF AIS SHOULD BE REVISED

Magnusson (18) review published in 1998 concluded that contractile reflex activity does not contribute to the response in a slow static stretch. Magnusson’s conclusion is valid also in regards to AIS. Alter (1) in his “Science of Flexibility” published in 2004 was strongly critical of the assumption of the stretch reflex in AIS (1 p.164). Taking into account these critics, the assumption of AIS, that the stretch reflex is activated if the stretch continues more than 2 sec, should be revised. It could be revised without any change in the way stretches are made. The change would only affect the way AIS is justified. It has been demonstrated above that the best justification for AIS is stretching along the stress lines of body and relaxation of the muscle to be stretched. Even in the future, AIS-stretches would be performed in 2 sec with low force and by the rhythm of breathing.

After the revision suggested above there would be no changes in the way AIS stretches are done. Therefore, experimental studies on the effect of AIS on increasing joint ROM would need no changes. Nor would there be any changes in the many ways AIS is used in sports. The warning that one should not stretch more than 2 sec is in fact useless and incorrect theoretical justification for AIS. To be better approved and appreciated, the revision is inevitable.
WOULD AIS INCREASE JOINT ROM MORE THAN STATIC STRETCHING?

Four studies on this subject were published in peer-reviewed journals. They fulfil the criteria of a scientific study. The studies have a randomized control group in addition to the two groups doing the AIS and static stretches. Randomized assignment of the subjects to the groups was secured. The studies were published as one page abstracts, which may reflect the somewhat poor status of AIS in sports medicine and exercise physiology.

1. McMahon et al. (24) evaluated 53 subjects who performed knee extension stretches 4 times·wk$^{-1}$ for 4 wks. The increase in ROM was statistically significant after the 1st wk of AIS and in static stretches after 2 to 4 wks. The AIS increase in ROM was significantly greater than for the static stretch exercise.

2. Liemohn et al. (13) studied 30 subjects who performed 9 exercises of straight leg raise in 3 wks. Both modes of stretching significantly increased ROM, but AIS increased ROM significantly more than the static stretch exercise.

3. Marino et al. (19) evaluated 30 subjects who were doing the straight leg raise stretch exercise 3 times·wk$^{-1}$ for as long as 13 wks. They reported that only the AIS significantly increased ROM. As to the static stretch increase in ROM, it was not significantly different from the control group.

4. Middag and Harmer (25) reported on 30 subjects who performed 5 times·wk$^{-1}$ for 3 wks knee extension stretches. AIS increased ROM more than 11% versus the 8% by static stretch, but the difference was not statistically significant.

In 2 of these 4 studies, AIS increased joint ROM significantly more than static stretch. In the Middag and Harmer’s (25) study, AIS increased more but the difference was not significant, and in Marino et al. (19) study, only AIS significantly increased ROM. Hence, the studies point out that AIS attains greater or at least the same increase in joint angles of the hamstring muscles than static stretch.

In the Lopez-Bedoya et al. (15) study, the findings indicated that static stretch increased the hamstring ROM more than AIS and more than hold-relax stretching. However, AIS was not correctly defined in the study, and the study procedures did not follow the ideas of Mattes book published in 2000, although the book was in the reference list of the study. Relaxation of the hamstring muscles in AIS exercises is specified incorrectly. The authors are suggesting that assisted AIS is the same as assisted active static stretches (AASS) with a 2-sec rest between repetitions and that during this 2-sec rest the muscle is relaxing. For example, “Training session was thus: 4 x 12 x (AASS 2 sec) with a 2-sec rest between repetitions and a 50-sec rest between series.” Relaxation of hamstrings is not taking place in this procedure. Hamstrings are truly relaxed in AAIS (assisted AIS),
where the stretching person is actively raising the leg as far as possible, and the assisting therapist is only finishing the stretch lightly, with less than 4.5 Nm torque.

Since relaxation of the muscle does not happen in AIS exercises in the study, one essential part of the effect of AIS on ROM is missing and, therefore, the conclusion of the study is not valid. AIS might as well be increasing ROM more than static stretch, but the study is not able to give the correct estimate. Same authors, this time in a different order, Vernetta-Santana et al. (29) published in 2015 another study on AIS. The study sets out to confirm that AIS will significantly increase joint ROM, but will not weaken significantly peak isometric force of the hamstring muscles. Definition of AIS is the same as in the previous Lopez-Bedoyan et al. (15) study with the same incorrect specification of relaxation of muscles. Therefore, the conclusions of the study are not likely to be reliable.

DISCUSSION

Active Isolated Stretching has been developed for more than 40 yrs, but its scientific basis has probably not been demonstrated until the earlier attempts by Mattes to get the research community to study AIS. But that there are still concerns as explained earlier. The suggested mechanisms of action of AIS should undergo further studies. After possible confirmation by research, these mechanisms would be a valuable tool of AIS in rehabilitation after sport injuries.

In fact, in this regards, Mattes made a 40-yr effort in developing and studying ~120 stretches for his 2012 book on AIS. The number of stretches is large and can serve the needs of rehabilitation in physiotherapy. The book has instructions both for stretches made by the client or patient him- or herself and/or by the help of an assisting person. Mattes would call the self-made stretches “active”, but it is contrary to the research community terminology. A large number of stretches for muscles and parts of muscles are needed in rehabilitation. AIS can isolate and focus the stretch more precisely than static stretches. For example, there are 6 AIS stretches for the hamstring muscles compared to two stretches in static stretching.

Strength training is also needed in rehabilitation and Mattes published in 2006 a book on strength training (22). The main idea of the book is similar to AIS in focusing strength exercises on each muscle if possible. During the 4 decades since the 1970s, several hundred AIS therapists have applied AIS to sport injuries and musculoskeletal problems. Rehabilitative AIS exercises are based on physiological principles. AIS-therapists have applied AIS in sports teaching, coaching, and assisted stretching. There is some indication that in elite level sports, where competition is especially hard and rewards high, AIS has made a breakthrough and many athletes prefer using it. This may have increased the use of AIS in sports, although there has been a tendency by athletes to hide the use of AIS in order to be more competitive. AIS therapists have also been teaching and training AIS to ordinary people. Mattes would suggest that stretching is almost a daily requirement, as muscles shorten, stiffen, and/or become tense from
work, training, and/or stress. In fact, that is one reason he published a book with the title “Specific Stretching for Everyone” with instructions for 99 AIS stretches (23).

It is interesting and questionable as well that sports medicine research has shown only so little interest in AIS. At least on the internet pages of the National Academy of Sports Medicine (NASM) is a text on “Current Concepts in Flexibility Training”, and AIS is one alternative stretching method (27). Active Isolated Stretches are suggested for warm-up before sports competitions or high-intensity exercises. But, NASM defines AIS in a markedly different way than Mattes. Relaxation of the muscle takes place in NASM’s definition of AIS, but stretching along the stress line of muscle is missing. When checking videos of the four example stretches of NASM for biceps femoris, quadriceps, adductors, and pectoral muscles, it appears that they are not consistent with the AIS - stretches in Mattes books of 2000 and 2012. Both relaxation of muscle and stretching along the stress line of muscle are required in AIS, and the definition that NASM is using for AIS is deficient. Without stretching along the stress line of muscle, stretches are producing less ROM, and also other positive effects of AIS are missing. This may be one reason, why the medical research community has lost the willingness to study AIS.

CONCLUSIONS

Aaron L Mattes in his many experiments succeeded in finding that stretching along the line of stress of the muscle and relaxation of the muscle to be stretched in each repetition of the stretch would diminish the resistance to stretching. Based on this finding, it has been demonstrated that AIS stretches are performed with less torque than static stretches of hamstring and calf muscles. Four studies show that AIS would attain greater or at least the same increases in joint ranges of hamstring muscles as the static stretches. The findings should be confirmed by additional scientific research.

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