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Does acute passive stretching alter the optimum height for drop jumping?

Jonathan Samuel Ritchie
Louisiana State University and Agricultural and Mechanical College, jritch2@tigers.lsu.edu

DOES ACUTE PASSIVE STRETCHING ALTER THE OPTIMUM HEIGHT FOR DROP JUMPING?

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TABLE OF CONTENTS

ABSTRACT

The application of static stretching (SS) has previously been shown to limit performance in force production, reaction time, balance and vertical jump height. When looking at the effect of SS on jump performance, researchers have previously used changes in jump height, in squat jumps (SQ), countermovement jumps (CMJ) and drop jumping (DJ) from self selected heights. To date no one has looked at the effect of SS across a range of drop heights. 30 subjects (15 male and 15 female) participated in 1 familiarization trial and four performance trials. All subjects undertook two days of stretching (ST) and two days of non-stretching (NS), in randomized fashion. The stretching protocol involved five lower body stretches. Each stretch was taken to the point of discomfort (POD) and held for 15 seconds with a rest period of 15 seconds, three times. Each stretch was performed both unassisted and assisted. This was followed by 10 minutes of quiet sitting. The NS group rested for a total of 33 minutes and 30 seconds. Both groups performed a sit and reach test on arrival and after the ST protocol / NS protocol. Each subject performed a total of 12 jumps from 6 different heights with 30 seconds rest between each jump per trial. Jump heights were calculated and ground contact times (GCT) measured using the AMTI force platform system. Two-way analysis of variance revealed that SS did not alter maximal vertical jump height ($p > 0.05$). Therefore this study has demonstrated that a lower body SS program (5 stretches, 90 seconds per stretch) did not alter DJ height.

1. INTRODUCTION

In 1998, Kokkonen et al. (18) published a paper challenging the previously widely accepted view that static stretching was an athletic performance aid. Stretching, till this point, was anecdotally accredited with being able to prepare athletes for competition, increase flexibility and range of motion (ROM), and aiding in the prevention of injuries. Consequently, static stretching has traditionally been used in the warm-up as an integral part of the athletic training program. Kokkonen et al. (18) took 30 physical education students and looked at the effects of a static stretching (SS) protocol on knee-flexion 1RM. They found that stretching resulted in an average decline of 7.3% in knee flexion 1RM, compared to the no stretch condition. Since its publication, numerous articles have been published examining the influence of SS on force production (1, 12, 25), jump height (6, 25, 27), ROM (33), electromyography measured muscle activation (8, 16), and reaction time and balance (1, 4). SS as a warm-up method has also been compared to dynamic stretching as a warm-up method (11, 16).

Static Stretching versus Dynamic Stretching

In comparison to SS, dynamic stretching uses active muscular effort and speed of movement to bring about a stretch, and unlike SS the end position is not held. Herda et al. (16) compared the acute effects of static and dynamic stretching on peak torque. They found that after SS peak torque significantly decreased at angles 81° and 101°, but that dynamic stretching did not significantly decrease peak torque at any angles. Fletcher and Anness (11) looked at combined static and dynamic stretching on 50m-sprint performance. They had three interventions: active dynamic stretch (ADS), static passive stretching combined with ADS (SADS), and static dynamic stretch combined with ADS (DADS). They found that when compared with ADS and DADS, SADS yielded significantly lower 50m-sprint performance times. These two papers indicate that not only does SS reduce peak torque and 50m-sprint performance but also that dynamic stretching is a more effective manor of preparing for competition.

Force Production

Recent studies have reported that SS can result in a reduction anywhere from 5% to 30% in power (32) and strength (3, 5, 12, 18, 20, 28). Such a loss in force production could potentially have dramatic effects on the outcome of a competitive result. At an elite level, athletes sometimes train to try to achieve gains as little as 1 to 2% over a season. If by warming up incorrectly they could potentially lose as much as 30% in force production (32), then all their hard work could be jeopardized.

As already mentioned, Kokkonen et al. (18) demonstrated the negative influence that SS has on 1RM strength production. Numerous other papers (1, 12, 25, 30, 33) have also considered the influence of SS on force production, and in the majority of cases, have found a performance detriment effect (3, 5, 12, 16, 25) or no effect at all (1, 25). Power et al. (25) looked at the effects of SS on maximal voluntary force (MVC) production in the quadriceps and plantar flexors (PF). They found a significant decrease of 9.3% across the 120-minute testing duration for the quadriceps. However, they did not find any significant decrement in performance for the PF. Power et al. (25) quantified this difference in muscle groups by noting that the gastrocnemius muscle, when stretched, was done solely by the participant. Although the participants were told to take the stretch to the point of onset of pain, this may not have induced the same stretch that was achieved for the quadriceps group, where the researcher assisted in the stretch. Alternatively, they also suggested that the non-significant result might be due to the contrasting effects of the skeletal architecture between the tibia and the foot; the foot possibly being able to dissipate some of the torque effects.

Contrary to the non-significant decrement in MVC for the PF, Fowles et al. (12) found a 25% loss in MVC as a result of 30 minutes of passive SS. There were notable differences between the stretching protocols of the two studies. Fowles et al. (12) put the PF under maximal passive stretch for a total period of 30 minutes, and the researchers assisted in achieving a higher degree of stretch. Power et al. (25) in contrast, stretched the PF for a total of 270 seconds, and the degree of stretch was participant dependant.

In addition to Power et al. (25), Alpkaya and Koclea (1) also did not find any significant decrement in explosive force. They found a non-significant decrease of 3.5% as a result of 3 sets of 15 seconds of SS of the PF. Perhaps, if the subject pool was increased from 15, or the stretching was assisted, rather than the degree of the stretching being determined by the participant, this result may have been significant. These differences in findings and differences in stretching protocol between studies indicate that there is a volume and intensity effect on force production.

Reaction Time, Movement Time and Balance

Reaction time and balance are both very important factors in sport performance and any loss of these proprioceptive factors will limit a sport performer's ability to compete at their highest level. Behm et al. (4) have shown that SS can impair balance, reaction time and movement time. They had their participants gently cycle for 5-minutes prior to a SS program of the hamstrings, quadriceps and PF. Each muscle group was stretched for a total of 135 seconds.

The control group experienced improvements in balance, reaction time and movement time from pre to post warm-up. Their warm-up consisted of a 5-minute cycle followed by a 26-minute rest period. This was in contrast to the stretch group who experienced significant decreases in performance across all three of the variables. What is interesting is that in this experiment the stretch group did not actually experience a loss in force production in comparison to the control group as both groups showed a decrease of 6.9% and 5.6% respectively. The paper did not mention whether or not the percentage decline in force production was significant inter-group pre to post. This result may indicate that proprioceptive factors, such as balance, reaction time and movement time are in fact more sensitive to the mechanisms of SS, than is force production.

Jump Height

Vertical jump height is a popular measure used to determine the influence of SS on performance. Squat jumping (SQ), counter movement jumping (CMJ) and drop jumping (DJ) are the three major types of jumps that are used to test for performance variables. Decrements in jumping performance have been demonstrated by a number of papers (3, 6, 8). Behm and Kibele (6) looked at the effects that differing SS intensities had on jump performance. They conducted a lower body SS routine. Each stretch was held for 30 seconds with 30 seconds rest in between each for a total of 4 stretches per muscle group. On different days the stretches were taken to 50, 75 and 100% point of discomfort (POD). Their DJ, CMJ (with a fast stretch shortening cycle (SSC)), CMJ (with slow SSC to 70% knee flexion), CMJ (self determined) and SQ jump heights were determined. Behm and Kibele

(6) found a significant decrement in performance across all jump conditions and all stretching intensities. What was most interesting about this study was that even at sub-maximal stretching intensities a performance decrement was shown. This is contrary to the study carried out by Young et al. (33), in which, they looked at the effect of SS intensity and volume on PF explosive force production. In one of their conditions, they had their participants stretch to 90% of POD for 2 minutes prior to performing a DJ from a height of 30 cm. Young et al. (33) found no significant difference in DJ performance. A key difference between these two studies was that Young et al. (33) only stretched the PF whereas Behm and Kibele (6) stretched the PF, the hamstrings and the quadriceps. Similarly, Knudson et al (20, 21) published two studies showing no significant decreases in performance as a result of stretching taken to a point "just before" discomfort. It is difficult to compare these studies as a point "just before" discomfort is a participant dependent interpretive measure.

Drop Jump Height Selection

A big question in DJ studies is the height at which the DJ should be performed. Studies that have used DJ as a means to assess the effects of stretching have tended to use singular heights (6, 25, 32, 34). Young and Elliott (34), Young and Behm (32) and Power et al. (25) all used a drop height of 30cm. Behm and Kibele (6) used a 24cm platform. All of the before mentioned researchers justified their height selection by stating that it would be high enough to stress the SSC, whilst allowing participants to emphasize a short ground contact time (GCT). By using a singular drop height you do not contend for individual differences in strength and ability. By ignoring individual factors in the selection of DJ height, you allow for the possibility of strength and jumping ability overriding or potentially adding to the effects of stretching, leading to the question of the validity of results. A possible alternative to using a single height for all subjects was used by McBride et al (22). They based the DJ height selection for each individual off of the participants CMJ performance. DJ height was equivalent to maximal CMJ height. This method eliminates differences in individual ability and should hopefully result in more reliable results when used as a performance measure for the effects of SS.

Why Does Stretching Alter Force Production?

There are two main theories as to why SS alters force production, and consequently jumping performance. The first being that of acute neural inhibition. SS is thought to alter the balance in the force-length characteristics of the muscle, which has a detrimental effect on proprioceptive feedback and co-ordination (13, 15). Power et al. (25) showed that as a result of SS of the PF, maximal voluntary contraction (MVC) was significantly inhibited for a period of 120 minutes as shown by a decrease in interpolated twitch technique (ITT). This inhibition was associated with muscle inactivation, indicating a possible neurological deficit. Fowles et al. (12) also found a decrease in activation as indicated by a significant 13% decrease in ITT, which corresponded with a significant force decrement of 20%, 5 minutes post SS.

The second theory put forth to explain the loss of force production and jump height as a result of SS is a reduction in muscle tendon unit (MTU) stiffness. A more compliant MTU is initially unable to transmit the available force to the bone, as it must first go through a period of unloaded contraction. A reduction in MTU stiffness leads to a lower rate of force production and a delay in muscle activation (3, 10, 15). Nelson et al. (24) looked at the effects of SS on maximal voluntary isometric knee extension torque at joint angles of 90°, 108°, 126°, 144° and 162°. They hypothesized that a more compliant MTU would cause the sarcomeres to shorten below their optimal length and thus greater force decrements would be seen at larger knee angles. Nelson et al. (24) showed that maximal voluntary isometric torque was only significantly different from pre-stretch values at joint angle of 162°, indicating that their hypothesis was correct.

Fowles et al. (12) showed that 30 minutes of SS of the PF resulted in a 28% loss in MVC. After 15 minutes, when PF activation levels had returned to normal, there was still a 13% reduction in MVC. This indicates that there is a mechanical and structural change in the muscle that results in a reduction in MVC.

It would appear that both play their part in reducing force production. It is most likely that neural and structural changes in the muscle are both responsible for initial decreases in performance, with neural effects wearing off after a period of approximately 15 minutes (12), and structural alterations persisting for up to approximately 2 hours (25).

Jump height (concentric performance) has been shown to increase through increased pre-activity and eccentric phase muscle activity (14), as is reflected by the significant difference in jump height between SQ and CMJ. If this theory holds true, then why is the same significant difference not found between CMJ and DJ. As increasing the drop height increases the eccentric load and hence the pre-activity of the muscle. A study by Ducomps et al. (9) indicates that a muscle's concentric performance during jumping is influenced by its eccentric / concentric balance. McBride et al (22) has shown that an increase in jump height is directly related to an increase in pre-activity in the agonist prime movers. As long as there is a positive energy balance jump height will continue to increase in conjunction with an increase in pre-activity. However once the energy balance becomes negative, jump height ceases to increase and begins to decline. Komi and Bosco (19) looked at changes in DJ height across a range of 20 to 100 cm. They also found no significant difference between CMJ and DJ height. Male participants had an average maximum jump height of 40.3 cm from a drop height of 63 cm, and female's 27.3cm from 47.6 cm. As drop height increases beyond 63cm and 47.6cm, the corresponding jump height declined.

SS has been shown to decrease DJ height (6, 25) but primarily from isolated self-selected heights. To date however no one has looked at the influence of SS on DJ across a range of heights.

Problem Statement

The negative influence of SS on a range of performance measure has been widely reported, however, to date, its influence on DJ has only been shown on isolated drop heights, and not across a range of heights. It is not known whether or not the influence of the stretches will become more apparent at higher drop heights or if there will be a consistent percentage difference between jump heights at all drop heights.

Hypothesis

It is hypothesized that jump height will increase with drop height, until the point at which the energy balance becomes negative resulting in a gradual decline in jump height. It is also hypothesized that the application of a SS program prior to DJ will result in a significant decrease in jump height across all of the drop heights.

Delimitations

The participants used for this study are kinesiology college students, hence a population of convenience, consequently they may not be of a similar training status, or of a similar motivation level to complete the study.

The participants will DJ across a range of heights from 15 to 75 cm. It is possible, but unlikely that some of the participants may not have reached their maximum jump height from the peak drop height of 75cm, limiting what we will see for their force production curve. It was not however deemed safe to allow untrained subjects to drop jump from heights beyond this point.

The formula used to calculate jump height, is based off the fundamental laws of dynamics (2). Samozino et al (29) calculated the error rate of this formula to be 3%. This is in comparison to kinematic analysis, which is considered the gold standard method of measurement. This formula has been used in previous research (1, 10, 21) and is an accepted method of calculation.

Limitations

Due to the subject population used for this study, the results will not be applicable to all groups. DJ is a training method used in explosive sports, but not an activity that is actively found in sport performance. Consequently the results may not exactly transfer into a sporting arena.

Definition of Terms

Drop Jump - A drop jump is also known as a rebound jump and it describes when a person drops from a height, lands on the ground and then jumps up vertically, as high, as possible. In a DJ the time spent on the ground between landing and take-off is generally as short as possible.

Counter Movement Jump – A CMJ is a jump that utilizes the SSC. The participant will initially flex at the ankle, knee, and hip joints before extending at these joints as rapidly as possible to provide vertical propulsion.

Squat Jump – The participant begins in a position of flexion around the ankle, knee and hip joints and concentrically contracts as quickly as possible to provide vertical propulsion. This type of jump eradicates the application of the SSC.

Static Stretching – A static stretch is when a position is assumed with a limb outstretched. The purpose is to elongate the muscle. It is passive in nature the position is held without further movement.

Range of Motion - The range through which a joint can be moved, usually its range of flexion and extension.

Point of Discomfort - The point of discomfort represents the limit to which a stretch can be taken before the onset of pain as a result of that stretch.

Ground Contact Time - This is the length of time that is spent on the ground between landing and take off in the DJ.

2. METHOD

Subjects

15 male (age 22.6 yrs, height 178.4 cm, body mass 80.5 kg) and 15 female (age 21.4 yrs, height 160.7 cm, body mass 57.3 kg) college students took part in this experiment. The subjects gave verbal and written consent to participate and the appropriate institutional review board approved the study.

Experimental Protocol

Each participant completed a total of 5 testing days (1 familiarization and 4 experimental). Where possible the testing was performed on consecutive days, with a maximum duration of 2 weeks being allowed for completion. The familiarization day required the subjects to undertake the DJ protocol to acquaint them with the technique required. The subjects were instructed to drop off the box onto the force platform and to rebound jump with maximal effort on all trials. They were also instructed to keep their hands on their hips throughout and to jump as vertically as possible. This was done to reduce horizontal travel and jump height calculation variability. They were also given a visual demonstration of what the DJ should look like.

The four experimental days consisted of 2 stretch (ST) and 2 non-stretch (NS). The order in which these were performed was done so in a randomized balanced fashion. Each participant performed a total of 12 DJ from 6 different drop heights (15cm, 27cm, 39cm, 51cm, 63cm, 75cm), 2 jumps per drop height. Thirty seconds of rest separated the two trials at each height as well as each set of jumps from the different heights. On each of the experimental days the DJ trials were preceded by either 23 minutes 30 seconds of quiet sitting (NS) or 23 minutes 30 seconds of SS. Also on each of the experimental days the participants performed a sit and reach test prior to and immediately after the ST/NS protocol. This was to establish the effectiveness of the SS protocol. There was also a ten-minute rest period after the post sit and reach test prior to the beginning of the DJ.

Stretching Protocol

The stretching protocol was based off that of Kokkonen et al. (18). Each participant performed a total of 5 stretches unassisted. Each stretch was performed three times consecutively for a period of fifteen seconds with a rest period of fifteen seconds between each stretch. The protocol was then repeated with the assistance of a researcher. The researcher actively pushed the subject into the stretch until they verbally acknowledged that they had reached the pain threshold. The stretches were designed to stretch the major trunk muscle groups (gastrocnemius, soleus, hamstrings, quadriceps and gluteals).

Instrumentation

A force platform (AMTI MSA - 6) was used to record the vertical ground reaction force and analysis was carried out with Visual 3D software. Exercise steps were used for the drop heights. Each step was 15cm tall, with a 3cm stacking overlap, this lead to an initial drop height of 15cm, followed by concurrent 12cm increases.

Calculations

To calculate the vertical jump height, the flight time (t_{air}) between take off and landing from the force platform must be measured. This will allow for the calculation of the vertical takeoff velocity (V_i) of the centre of gravity as follows:

$$V_i = \frac{1}{2} \times t_{air} \times g$$

g represents the acceleration of gravity at 9.81 m/s^2

The vertical displacement of the center of gravity can then be calculated as follows:

$$h = V_i^2 / 2xg$$

GCT was also recorded to help establish if pre-activity of the muscle was a factor in jump height.

To assure the calculations were as accurate as possible, the subjects were instructed to jump as vertically as possible, as the formula assumes that take off and landing are from the same point. If the participant was unable to jump vertically, they were asked to repeat the trial. Komi and Bosco (19) used the before mentioned calculation method to establish vertical jump height they also filmed 6 jumps to compare the error rate between the film method and calculation method and found it to be 2%.

Statistical Analysis

A 2-way analysis of variance (ANOVA) was used to determine whether or not there was a significant effect of passive SS on DJ performance and an effect of increase in box height on DJ height. A 2-way analysis of variance (ANOVA) was also used to determine whether or not passive SS significantly decreased GCT in comparison to a NS group. It also determines if increasing DJ height significantly increased GCT. To test for effectiveness of the stretching protocol, a 2-way analysis of variance (ANOVA) was used to compare sit and reach performances. A significant main effect was analyzed using the Scheffe's post hoc multiple comparisons test. Standard error of the estimate was also calculated for the ST and NS conditions across all the jump heights.

3. RESULTS

Stretching Effectiveness

To assess the effectiveness of the stretching protocol a sit and reach was done prior to and after both conditions. It was found that there was a significant difference between ST and NS ($F\ (1, 29)\ 30.096$, $p < 0.001$) and between pre and post ($F\ (1, 29)\ 33.716$, $p < 0.001$). Post hoc analysis showed that post ST sit and reach was significantly greater than pre ST and the two NS conditions. It also showed that there was no significant difference between pre and post NS and pre ST.

Group Comparison

The results show that there was no significant difference between the ST and NS conditions across any of the drop heights ($F\ (5, 359) = 0.994$, $P = 0.424$). Figure 1 illustrates well the similarity in jump performance for the two conditions at all drop heights. What also should be noted from figure 1 is the great variation in jump height at different drop heights between individuals. This indicates a large variation in performance.

Effects of Increasing Drop Height

When comparing change in jump height as a result of increasing drop height, it was found that there was a significant difference between heights ($F\ (5, 359)\ 5{,}612$, $p<0.001$). However a Scheffe' post hoc analysis revealed that the difference was only found between drop height 1 and 6. There were no other significant differences found in jump height as a result of increasing drop height. The average jump heights for both the NS and SS conditions are shown in figure 1. What should be noted here is the uniformity in jump performance. From box height 1 to box height 6 there is only a difference of 2 cm.

The standard error of the estimate (SEE) for each jump height was 5% and this was true for both conditions. With such a high SEE it makes it hard to find a significant result.

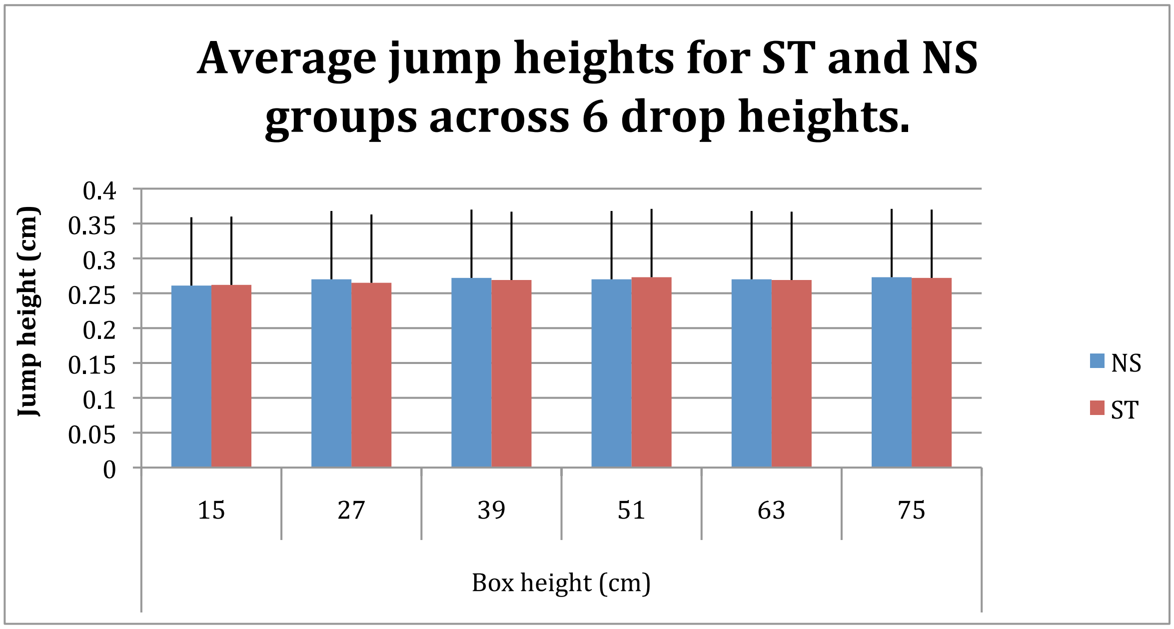

Figure 1: Graph showing the comparison between the SS and NS groups across the six different jumps heights.

Ground Contact Time

GCT were also recorded to see if there was a difference in pre-activity between conditions and whether or not it increased with increasing drop height. It was found that there was no significant difference between groups (F (5, 359) 1.237, P = .294) but there was a significant effect of drop height (F (5, 359) 36.772, P< 0.0001). Table 1 represents a comparison of the average GCT for each group across all six-drop heights.

Table 1: Average GCT (seconds) for both groups across all 6 drop heights.

	1 (15cm)	2 (27cm)	3 (39cm)	4 (51cm)	5 (63cm)	6 (75cm)
NS	.463	.48	.496	.507	.527	.533
SS	.472	.486	.504	.507	.523	.545

A post hoc Scheffe' Comparison test was run and it found that the GCT for drop height 1 was significantly different from drop height 3, 4, 5 and 6, drop height 2 from 5 and 6, 3 from 6, 4 from 6, 5 from 1 and 2 and 6 from 1, 2 and 3.

4. DISCUSSION

Contrary to the expectations of this study, the application of five lower body stretches, taken to the POD (assisted and unassisted) did not illicit a significant decrease in DJ performance across any of the six different drop heights. In addition, it was also found that increasing drop height only resulted in a significant difference between boxes 1 and 6 in DJ height for both the SS and NS groups. Both groups achieved an average jump height of 27cm.

Jump Height

The expectation that dropping height would influence the height of rise of the center of mass was based primarily on the results from Komi and Bosco (19). Komi and Bosco (19) looked at the effects of different drop heights on jump height and found a significant increase in jump height for males, when the drop height was increased from 26cm up to 62cm, and for females, when it was increased from 20cm up to 50cm. Read and Cisar (26), who were looking at the effect of differing rest intervals on DJ performance, did not add weight to Komi and Bosco's (19) findings. They looked at the effects of 15, 30, and 60-second rest intervals on DJ performance and found that in two of the rest conditions (15 and 60 seconds) there was no significant difference in jump performance across all ten trials (10 to 80cm). However, they did find a significant difference in the 30-second rest period trial, where trials 3 and 4 were significantly less than the respective jump height for trial 10. Read and Cisar (26) concluded that this result was an anomaly due to the fact that the same deficit was not achieved in either a lesser or greater rest interval protocol.

There is no outstanding reason why these two studies come to separate conclusions, although there are a few differences between the studies. Read and Cisar (26) did not place any restrictions on how the participants could jump, meaning that they were able to counter swing their arms. This did not lead to greater jump heights, so it would be unlikely to have caused a non-significant effect of drop height on jump height. Read and Cisar (26) also used a digitized method to calculate their jump heights, whereas Komi and Bosco (19) only filmed six of their trials, in order to establish the error rate of the calculation method. They established a 2 % error rate, and again, this is unlikely to be great enough to generate a masked result.

McBride et al (22) showed that there was no significant difference between CMJ and DJ as a result of a negative energy balance, which is brought on by increasing the load of a DJ. This current study did not collect EMG or ITT data, and so pre activity and energy balance across the range of drop heights cannot be compared. It is possible that the consistency in jump heights for both groups across all drop heights maybe as a result of increasing pre activity being balanced out by an increasing negative energy balance, also generated by the increase in drop height. Although EMG and ITT data was not collected, this research did show that as the drop height increased, so did the GCT. Increased GCT indicates that the participants were trying to increase their impulse (force x time), through increased pre-activity with increased drop height. This lends some support to the above argument, but in order to see if this is really the case, further data would need to be collected. It is also possible that drop height would need to be increased beyond the 75cm drop height, before a decrease in jump height could be established.

Static Stretching versus Non Stretching

The non-significant difference between the NS and the SS conditions was also not an expected result. It was thought that as a result of the SS routine, there would be significant decreases in jump height across all drop heights. As to why this may not have been the case, could have been the result of a number of different factors.

Behm and Kibele (6) showed that as a result of a lower body SS routine taken to the POD DJ performance decreased by 3.8%. The SEE for this study averaged around 5% for each specific drop height and across both SS and NS conditions. A 5% SEE represents a value greater than the expected decrease in performance, therefore it is unlike with such an error rate that it would be possible to find a significant difference in performance between the NS and SS conditions.

A possible reason for the large SEE and the variability in jump performance between all of the subjects could be the complexity of the DJ as a skill. In this current study all of the participants undertook one day of familiarization. However there is the possibility that this may not have been adequate enough for them to master the skill, especially as the subject population was a group of novices, and consequently it is unlikely that DJ would have been familiar to them. In order for a DJ to be performed correctly the individual requires high levels of co-ordination and timing. If it is performed incorrectly then this can drastically affect the corresponding jump height achieved. The participants were asked to follow a number of restrictive protocols, including jumping as vertically as possible and limiting GCT. Adding in these additional thought processes to the jump could have dramatically reduced their ability to perform the DJ correctly. The participants were also asked to keep their hands on their hips throughout the DJ. This again could have induced variability into their jump performance, as the arms are essential to balance and co-ordination. By eliminating them from the jump you increase the chance of forward rotation on take-off from the force platform.

When comparing the performance of the these participants against those of the Komi and Bosco (19) study, who used a similar population of novices, it becomes clearer that this group did not perform the skill as well as could have been expected. Males and females combined had an average overall jump height of 27cm for both the NS and SS conditions. Comparatively speaking women had an average jump height of 27.3 cm and males had an average jump height of 40.3cm in the Komi and Bosco (19) study. Even though this data has not been broken down on a basis of gender. Komi and Bosco (19) showed that in general males performed 54 to 67% better than their female counterparts. If this gender difference in DJ performance is correct then you would expect a combined average jump height for males and females to be somewhere in between 27.3cm and 40.3cm. But as can be seen in this study the combined average DJ height for males and females equals that of females in the Komi and Bosco(19) study. This below par performance lends support to the idea that these participants had not mastered DJ as a skill and consequently had reduced jump heights and increased variability.

There are other possibilities to explain the variability in results. One is that the subjects lacked sufficient motivation to elicit a maximum performance. DJ is an explosive activity that requires the participant to give 100% effort on every jump. If a number of participants did not give this effort, then it most definitely could have skewed the results. The researchers were aware of this possibility prior to the beginning of the study, and consequently, made sure to reinforce the importance of jumping as high as they could at the beginning of every day and during the trials themselves. Reinforcement of the protocol does not rule out the possibility that the participants did not give their maximum effort across all 56 jumps.

In this current study, the stretching protocol used was 5 lower body stretches that targeted the gastrocnemius, soleus, hamstrings, quadriceps and gluteals. Each stretch was performed 3 times for a total of 45 seconds (15 seconds of stretch followed by 15 seconds of rest). The protocol was performed unassisted and then assisted, with the exception of the gastrocnemius and soleus stretch, which was performed unassisted on both occasions. A sit and reach test was performed pre and post stretching to assess for changes in muscle compliance. The significant increase of 14% from pre to post in the SS group indicates an alteration in the length and stiffness in the MTU of the hamstrings and helps to support the effectiveness of the stretching protocol. Power et al (25) saw a similar increase in the sit and reach (10%), but did not find a significant decrease in jump height. The sit and reach test that was used, is a representative test of flexibility of the hamstrings and lower back and so even though there was a significant increase in the sit and reach as a result of the stretching routine, this does not necessarily indicate that there was a stretch induced in the PF, quadriceps, and hip flexors.

Although GCT significantly increased with drop height for both groups, there was no significant difference as a result of stretching. Behm and Kibele (6) and Power et al. (25) both reported non-significant increases in GCT, which is in agreement with the GCT results found in this study. Although non-significant, both groups showed a trend towards increased GCT. Power et al. (25) suggested that the increased GCT represented an increase in muscle compliance and further contributed to their observed significant decrease in force production. Even though Power et al. (25) showed a decrease in force production as a result of SS, they also did not see a decrease in DJ height as a result of the same stretching protocol.

Yoon et al. (31) showed that performance in DJ is highly linked to ankle joint torque at midpoint, which is enhanced by greater ankle joint stiffness during the eccentric phase of the jump. Young and Elliott (34) demonstrated a significant decrease in DJ performance as a result of SS and suggested that this may be a result of a decrease in MTU stiffness. Although the SS protocol used in this research incorporated both unassisted and assisted components, solely the participant performed the SS of the PF. Therefore, even though they were told to stretch to the POD, the relative tension put on the stretch could not be determined by the researcher. Consequently, it is possible that if the participants did not induce a stretch great enough to lengthen the MTU and reduce compliance, then the joint torque would have been unaffected by the stretching routine leading to a non significant reduction in performance.

In addition to this the PF stretch that was used was performed with the knee in a locked position. When this stretch is performed in this manner it focuses the stretch on the gastrocnemius and not the soleus. In order to change the focal point of the stretch it should have been repeated but with the knee in a flexed position allowing the soleus to be targeted. Consequently even if the gastrocnemius was stretched adequately the soleus and achilles tendon part of the gastrocnemius muscle-achilles tendon complex was not, therefore diminishing the negative effects of the stretching protocol on ankle joint stiffness and its associated power outputs. This is of particular relevance as Bobbert et al. (5 (5) has shown that in the DJ the ankle joint's contribution to power output is substantially greater than that of the knee and hip joints.

The majority of SS protocols that have been carried out have concentrated on 2 – 3 lower body muscle groups and generally lasted between 20 – 30 minutes (5, 12, 18, 25). Although these studies found significant decrements in force, the stretch durations that they employed are not representative of SS routines that are used in warm-ups. Contrary to the force production studies, relatively few (23, 34) have found a decrease in vertical jump as a result of SS programs that are held for 15 – 30 seconds over 2 – 3 muscle groups. In this study, each muscle group was stretched for a total time period of 90 seconds (45 unassisted and 45 assisted). Robbins and Scheuermann (27) looked at the effect of varying amounts of acute SS on vertical jump performance and found no stretch effect on performance until post 6 sets of 15 seconds of stretch. Although the total stretch time in this study was 90 seconds, the unassisted stretches were performed prior to the assisted stretches, allowing for a rest period of 10 minutes in-between. Although significant decreases in DJ height have been shown before, the stretch duration has tended to be greater than the 90 seconds used in this protocol. Behm and Kibele (6) used a total stretch duration of 120 seconds per muscle group and found a significant decrease in performance. Young et al (33) showed an effect of stretching for 120 and 240 seconds of stretch plus a 5-minute, run but not for 60 seconds of stretch plus a run. In order for a stretch time effect on DJ to be established, further research must be conducted.

Changes

If I were to conduct this study again, there are a few changes that I would make to the protocol of the study.

I believe that I possibly underestimated the complexity of the DJ. This under-estimation resulted in great variability in the performance of the subjects and may have resulted in the expected results not being apparent. In this current study, each subject underwent one day of familiarity, it may have been more appropriate for the subjects to undertake 3 to 4 days of practice and to have the use of their arms for purposes of balance.

Although the sit and reach test is a good indication that the stretching protocol was effective in stretching the hamstrings, it does not reflect the effectiveness of the other stretches. In this study, I used a straight leg heel cord stretch. This stretch targets primarily the gastrocnemius. By repeating the same stretch but also bending the knee, it moves the emphasis from the gastrocnemius to the soleus and the achilles tendon. This should result in increased compliance of the gastrocnemius muscle-achilles tendon complex.

The other potential change that could be made is the way in which the jump height is calculated. As reported, there is a 3% error rate with the current jump height calculation, due to the assumptions of the equation. To eradicate this 3% error rate, the jumps could be recorded and digitized to calculate the exact rise of the pelvic crest in comparison to standing.

Conclusion

Due to primarily the complexity of the DJ as a skill, this group of novice participants were unable to achieve consistency in jumping, resulting in a large amount of variability. This level of variability has masked any potential stretch effort, making it impossible to draw any realistic conclusions as to whether or not a lower body SS routine alters the optimum height for DJ.

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APPENDIX: INTERNATIONAL REVIEW BOARD

ACTION ON PROTOCOL APPROVAL REQUEST

LSU
Institutional Review Board
Dr. Robert Mathews, Chair
203 B-1 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu | lsu.edu/irb

TO: Arnold Nelson
Kinesiology

FROM: Robert C. Mathews
Chair, Institutional Review Board

DATE: November 18, 2008
RE: **IRB#** 2900

TITLE: Does acute passive stretching alter the optimum height for drop jumps

New Protocol/Modification/Continuation: New Protocol

Review type: Full ___ Expedited X   **Review date:** 11/17/2008

Risk Factor: Minimal X Uncertain ______ Greater Than Minimal_______

Approved X **Disapproved**__________

Approval Date: 11/17/2008 **Approval Expiration Date:** 11/16/2009

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 60

Protocol Matches Scope of Work in Grant proposal : (if applicable)_______

By: Robert C. Mathews, Chairman Robert C. Mathews

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

VITA

Jonathan Ritchie was born and raised in Portadown, Northern Ireland. He lived there for the first eighteen years of his life and attended Edenderry Primary School, Killicomaine Junior High School and Portadown College. When he graduated from College, he moved to Scotland where he studied applied sport sciences at The University of Edinburgh. He graduated in 2004 with a Bachelor of Science in applied sport science. For the next three years, he worked for the Center for Sport and Exercise at The University of Edinburgh before deciding to continue his education in U.S.A. In August 2007, he moved to Baton Rouge and attended Louisiana State University, where he studied exercise physiology under Associate Professor Arnold G. Nelson. He expects to graduate in August 2009 with a Masters in Kinesiology.