LATENT EFFECT OF PASSIVE STATIC STRETCHING ON DRIVER CLUBHEAD SPEED, DISTANCE, ACCURACY, AND CONSISTENT BALL CONTACT IN YOUNG MALE COMPETITIVE GOLFERS

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ABSTRACT

Gergley, JC. Latent effect of passive static stretching on driver clubhead speed, distance, accuracy, and consistent ball contact in young male competitive golfers. *J Strength Cond Res* 24(12): 3326–3333, 2010—This investigation was conducted to determine the effect of 2 different warm-up treatments over time on driver clubhead speed, distance, accuracy, and consistent ball contact in young male competitive golfers. Two supervised warm-up treatments, an active dynamic warm-up with golf clubs (AD) and a 20-minute total body passive static stretching routine plus an identical AD warm-up (PSS), were applied before each performance testing session using a counterbalanced design on nonconsecutive days. Immediately after the AD treatment, subjects were instructed to hit 3 full swing golf shots with their driver with 1-minute rest between trials. Immediately after the PSS treatment, subjects were instructed to hit 3 full-swing golf shots with their driver at t_0 and thereafter at t_{15}, t_{30}, t_{45}, and t_{60} minutes with 1-minute rest between swing trials to determine any latent effects of PSS on golf driver performance measures. Results of paired *t*-tests revealed significant ($p < 0.05$) decreases in clubhead speed at t_0 (−4.92%), t_{15} (−2.59%), and t_{30} (−2.19%) but not at t_{45} (−0.95) or t_{60} (−0.99). Significant differences were also observed in distance at t_0 (−7.26%), t_{15} (−5.19%), t_{30} (−5.47%), t_{45} (−3.30%), and t_{60} (−3.53%). Accuracy was significantly impaired at t_0 (61.99%), t_{15} (58.78%), t_{30} (59.46%), and t_{45} (61.32%) but not at t_{60} (36.82%). Finally, consistent ball contact was significantly reduced at t_0 (−31.29%), t_{15} (−31.29%), t_{30} (−23.56%), t_{45} (−27.49%), and t_{60} (−15.70%). Plausible explanations for observed performance decrements include a more compliant muscle–tendon unit (MTU) and an altered neurological state because of the PSS treatment. Further, the findings of this study provide evidence supporting the theory that the mechanical properties of the MTU may recover at a faster rate than any associated neurological changes. The results of this inquiry strongly suggest that a total-body passive static stretching routine should be avoided before practice or competition in favor of a gradual AD. Athletes with poor mechanics because of lack of flexibility should perform these exercises after a conditioning session, practice, or competition.

KEY WORDS muscle–tendon unit (MTU), reflex sensitivity, neural inhibition, range of motion (ROM)

INTRODUCTION

The sport of golf requires a high level of joint flexibility that allows the human body to generate powerful biomechanical producing positions maximizing the leverage of the human body (6,27,44). During the full-swing adequate range of motion (ROM) when learning and executing the golf full swing is well documented and has historically been a significant interest of the Professional Golfers Association and competitive golfers worldwide (6,44). Therefore, many competitive golfers have added stretching exercises to their normal practice regimens. The benefits of stretching exercises include a reduced chance of injury (12,13,32,34,36), enhanced biomechanical efficiency (5,11,20), and generation of higher clubhead speeds (5,11,20,41,42). Indeed, competitive golfers choosing to include flexibility training as part of their preparation for competition is becoming the norm rather than the exception (11,44).

Static stretching exercises are commonly used during the warm-up phase before practice or competition in sport activities (3,21). As referenced above, the general belief is that increased ROM will translate into reduced incidence of injury (34,36,40). Interestingly however, a recent investigation provided evidence that the acute effects of stretching may

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be harmful because of joint instability (26), whereas another study reported a higher incidence of injury in subjects with very high or low levels of flexibility (9). Hence, the inquiry of whether a greater ROM contributes to the prevention of musculoskeletal injuries remains controversial.

From a performance perspective, several contemporary studies have examined the effects of various stretching modalities and reported decreased maximal isometric strength (1,4,15,29), decreased isokinetic peak torque (30), decreased dynamic strength (24,28–30,45), decreased muscular endurance (16), decreased sprint performance (14,43), and decreased vertical jump (5,8,28). Thus, it may be detrimental to stretch before practice or competition. These findings have implications for the sport of golf because high levels of sequenced force production from the legs through the torso into the arms and hands are necessary to generate maximum clubhead speed (6,20,27,41,44). Furthermore, consider that young competitive men generate driver clubhead speeds in excess of 45 $m \cdot s^{-1}$, thus requiring tremendous power output and coordination (6,20,44).

The mechanisms responsible for the stretch-induced decreased force production remain speculative (4,15). Plausible explanations include a more compliant muscle–tendon unit (MTU) (8,24,29,30), decreased neuromuscular reflex sensitivity (1,2,25), neural inhibition (1,4,15,39), and tissue damage because of creatine kinase associated with passive static stretching (37). Localized impairment has also been explained because of joint angle (10,25), contraction types (8,45), or contraction velocities (30).

A recent investigation specific to the golf full swing found acute decreases in driver clubhead speed, distance, accuracy, and solid contact after a total-body passive static stretching routine (17,18). These findings confirm previous investigations focusing on the acute effect of passive static stretching on performance measures in other sport movements. Additional studies have reported a latent time interval necessary for recovery from passive static stretching (15,31). Therefore, it is possible that the acute effects of passive static stretching may diminish overtime. Thus, this investigation was designed to determine what latent effects (i.e., performance measurements over time), if any, would remain on golf driver performance measures in male competitive golfers following warm-up protocols previously applied by Gergley (17,18). It was hypothesized that any impairment in the force dependent measures (i.e., speed and distance) would support the explanation that reduced force production is because of a more compliant MTU and an altered neurological state (i.e., dual effect) while impairment in the coordination dependent measures (i.e., accuracy and solid contact) would support the explanation of only an impaired neurological state (i.e., single effect) because of the passive static stretching plus an identical active dynamic warm-up with golf clubs (PSS) treatment. This study is of value because no well-designed and controlled studies have attempted to identify the time interval necessary to recover from passive static stretching in the sport of golf, and it may also contribute to the understanding of stretching induced impairment in sports requiring both fine and gross motor skills.

Methods

Experimental Approach to the Problem

Two different warm-up treatments (AD and PSS) were performed by all study volunteers before performance measurements. The AD treatment was selected because it is a

Table 1. Subject demographics (values are mean and *SD*).*

	Age (y)	Height (cm)	Body mass (kg)	Handicap (USGA formula)
Subjects	20.4 (1.8)	182.8 (6.1)	79.9 (7.1)	3.2 (1.6)

*USGA = United States Golf Association.

Table 2. Active dynamic warm-up progression with golf clubs.

1. Ten practice swings with a 1.13-kg weighted club (Momentus®)
2. Three full-swing shots with a sand wedge
3. Three full-swing shots with 8 iron
4. Three full-swing shots with 4 iron
5. Three full-swing shots with fairway metal wood
6. Three full -wing shots with driver

Table 3. Passive static stretching warm-up exercises (numbers indicate exercise order).*

1. Neck stretch
2. Chest stretch
3. Posterior shoulder
4. Inferior shoulder
5. Side bend
6. Quadriceps stretch
7. Back extensor stretch
8. Prone back stretch
9. Reverse trunk twist
10. Trunk twist
11. Hamstring stretch
12. Calf stretch

*Adapted from Hetu and Faigenbaum (20).

well-accepted warm-up progression frequently used by skilled golfers and it was very similar to the range of warm-up procedures normally applied by the subjects in this study. The addition of passive static stretching exercises in PSS treatment was different from the subjects' normal warm-up procedure. Hence, the author was interested in the impact of passive static stretching on golf performance measures immediately post at t_0 and at t_{15}, t_{30}, t_{45}, and t_{60} minutes post to identify a possible recovery curve. Measures of clubhead speed, distance, accuracy, and consistent ball contact were recorded at 2 different sessions on nonconsecutive days immediately after being exposed to each warm-up treatment. The dependent measures were selected based upon the logistical variables germane to all golf shots–distance and direction. Specifically, distance is a function of clubhead speed and solid ball contact, whereas direction is a result of applying the clubhead to the golf ball in a sequenced, coordinated manner. Any impairment because of PSS would manifest itself in these measures.

Subjects

The study subjects ($n = 9$) were young male competitive golfers who regularly participate in endurance, strength, and flexibility programs. Golf conditioning programs of this nature typically include multimode low to moderate cardiorespiratory training, multiple set total-body resistance training, and multiple rep total-body flexibility training. A United States Golf Association (USGA) handicap index of 5 or lower reflecting a high level of skill and recent participation in competitive golf was required for participation in the study. Before testing, the subjects were provided with a complete written and oral explanation of the study. After the explanation, each subject was asked to sign an informed consent document that was approved by Stephen F. Austin State University's Institutional Review Board. Table 1 outlines subject demographics and skill level expressed by the USGA handicap.

Procedures

The application of the warm-up treatments to the subjects incorporated a counterbalanced design. The AD warm-up treatment began with 10 practice swings with a Momentus® (Mt. Pleasant, IA, USA) 1.13-kg weighted golf club. Next,

Table 4. Percent change comparisons between AD and PSS over time.*

Comparison	Speed	Distance	Accuracy	Contact
AD with PSS_0	−4.92†	−7.26†	61.99†	−31.29†
AD with PSS_{15}	−2.59†	−5.19†	58.78†	−31.29†
AD with PSS_{30}	−2.19†	−5.47†	59.46†	−23.56†
AD with PSS_{45}	−0.95	−3.30†	61.32†	−27.49†
AD with PSS_{60}	−0.99	−3.53†	36.82	−15.70†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†$p < 0.05$.

Table 5. Golf performance variables at PSS_0.*

	AD		PSS_0		
Measure	Mean	*SD*	Mean	*SD*	*t*
Clubhead speed ($m \cdot s^{-1}$)	48.46	7.36	46.08	6.08	−6.12†
Distance (m)	249.50	16.75	231.38	12.65	−6.34†
Accuracy (m)	5.42	3.10	8.77	2.34	2.80†
Solid contact (answer of yes)	0.96	0.11	0.66	0.16	−3.42†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†A significant ($p < 0.05$) difference was observed between warm-up treatment means.

Table 6. Golf performance variables at PSS_{15}.*

	AD		PSS_{15}		
Measure	Mean	*SD*	Mean	*SD*	*t*
Clubhead speed ($m \cdot s^{-1}$)	48.46	7.36	47.20	6.50	−3.86†
Distance (m)	249.50	16.75	236.56	15.39	−5.55†
Accuracy (m)	5.42	3.10	8.60	0.21	3.34†
Solid contact (answer of yes)	0.96	0.11	0.66	0.16	−4.47†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†A significant ($p < 0.05$) difference was observed between warm-up treatment means.

each subject hit 15 full-swing shots with their competition golf clubs. Subjects progressed through their set from shorter, heavier clubs to longer, lighter clubs and ultimately concluded the AD treatment with their driver. Table 2 outlines the AD warm-up progression.

The PSS began with a 20-minute stretching routine. The stretching exercises included in the routine were selected with the objective of stretching the entire body and golf specific musculature. Table 3 outlines the stretching exercises and their order. Hetu and Faigenbaum (20) offer a more detailed explanation of these stretching exercises. Each subject performed 3 repetitions of 10 seconds for each stretching exercise. Immediately after passive static stretching, each subject proceeded to perform an identical AD warm-up described above.

TABLE 7. Golf performance variables at PSS_{30}.*

Measure	AD Mean	AD *SD*	PSS_{30} Mean	PSS_{30} *SD*	*t*
Clubhead speed ($m \cdot s^{-1}$)	48.46	7.36	47.40	6.37	−2.52†
Distance (m)	249.50	16.75	235.85	14.85	−4.30†
Accuracy (m)	5.42	3.10	8.63	1.96	2.72†
Solid contact (answer of yes)	0.96	0.11	0.73	0.14	−4.00†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†A significant ($p < 0.05$) difference was observed between warm-up treatment means.

TABLE 8. Golf performance variables at PSS_{45}.*

Measure	AD Mean	AD *SD*	PSS_{45} Mean	PSS_{45} *SD*	*t*
Clubhead speed ($m \cdot s^{-1}$)	48.46	7.36	48.01	6.02	−1.91
Distance (m)	249.50	16.75	241.27	13.04	−2.58†
Accuracy (m)	5.42	3.10	8.74	2.02	3.25†
Solid contact (answer of yes)	0.96	0.11	0.69	0.11	−5.29†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†A significant ($p < 0.05$) difference was observed between warm-up treatment means.

TABLE 9. Golf performance variables at PSS_{60}.*

Measure	AD Mean	AD *SD*	PSS_{60} Mean	PSS_{60} *SD*	*t*
Clubhead speed ($m \cdot s^{-1}$)	48.46	7.36	47.98	6.76	−1.82
Distance (m)	249.50	16.75	240.69	13.26	−3.46†
Accuracy (m)	5.42	3.10	7.48	2.31	2.01
Solid contact (answer of yes)	0.96	0.11	0.81	0.17	−2.52†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†A significant ($p < 0.05$) difference was observed between warm-up treatment means.

After the AD treatment, subjects were instructed to hit 3 full-swing shots with their driver. For measurement consistency across the sample, subjects were instructed to go through their normal preshot routines as if they were competing and used a 1-minute of rest between shots for the purpose of regenerating metabolic energy that had been used in the previous swing trial. After the PSS treatment, subjects were instructed to hit 3 full-swing shots at t_0 and thereafter at t_{15}, t_{30}, t_{45}, and t_{60} minutes post PSS treatment. All golf shots were hit with brand new Titleist® (Fairhaven, MA, USA) Pro V1 golf balls. Measures of clubhead speed were made using the Beltronics Swingmate® (Mississauga, Ontario, Canada) laser swing speed measuring device. The distance of each shot was measured using the Bushnell® (Overland Park, KS, USA) Pinseeker 1500 laser range finder. Accuracy was measured by the absolute distance each shot deviated, right or left, from the predetermined target line. Finally, consistent ball contact was measured using subjective feedback from each subject by asking the question, "How well did you hit that one?" and recording yes for solid contact and no for poor contact. This type of subjective measure, although not empirical, is appropriate for golfers at this skill level (44).

Statistical Analyses

To determine the effect the 2 different stretching treatments on clubhead speed, distance,

Table 10. Comparison of warm-up treatments on golf performance variables.*

Measure	AD		SS		
	Mean	*SD*	Mean	*SD*	*t*
Clubhead speed ($m \cdot s^{-1}$)	48.15	2.59	46.43	4.55	−9.60†
Distance (m)	245.69	12.02	231.86	13.48	−7.04†
Accuracy (m)	4.51	1.43	5.91	0.97	4.05†
Solid contact (answer of yes)	8.20	0.68	6.86	0.92	−6.32†

*AD = active dynamic warm-up with golf clubs; PSS = passive static stretching routine plus an identical AD warm-up.
†A significant ($p < 0.001$) difference was observed between warm-up treatment means.

accuracy, and consistent ball contact measurements, a paired *t*-test for 2 sample means was used. Specifically, AD measurements were compared with PSS measurements at t_0, t_{15}, t_{30}, t_{45}, and t_{60} minutes post. This method provides a statistical measure of actual mean differences between treatment applications at selected intervals over time. Statistical significance for comparisons was set at $p \leq 0.05$.

Results

The subjects in this study were tested for driver clubhead speed, distance, accuracy, and consistent ball contact after AD and PSS warm-up treatments over time. Results of paired *t*-tests revealed significant ($p < 0.05$) decreases in clubhead speed at t_0 (−4.92%), t_{15} (−2.59%), and t_{30} (−2.19%) but not at t_{45} (−0.95) or t_{60} (−0.99). Significant differences were also observed in distance at t_0 (−7.26%), t_{15} (−5.19%), t_{30} (−5.47%), t_{45} (−3.30%), and t_{60} (−3.53%). Accuracy was significantly impaired at t_0 (61.99%), t_{15} (58.78%), t_{30} (59.46%), and t_{45} (61.32%) but not at t_{60} (36.82%). Finally, consistent ball contact was significantly reduced at t_0 (−31.29%), t_{15} (−31.29%), t_{30} (−23.56%), t_{45} (−27.49%), and t_{60} (−15.70%). See Table 4 for percent changes by dependent measure over time and Tables 5–9 for means, *SD*s, and *t*-statistics for dependent measures at selected time intervals.

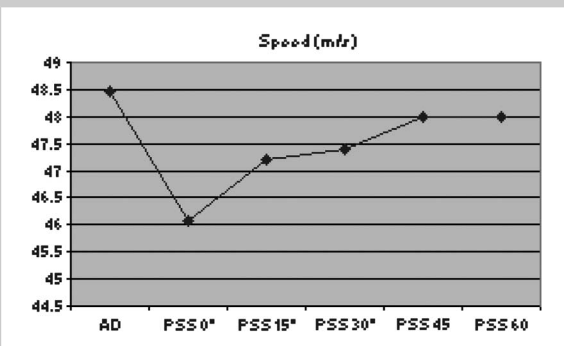

Figure 1. Clubhead speed means by treatment over time. *α = 0.05.

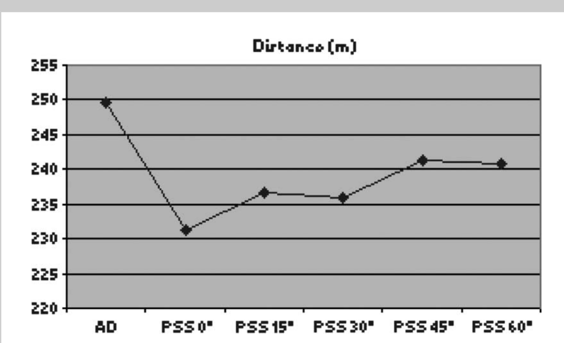

Figure 2. Distance means by treatment over time. *α = 0.05.

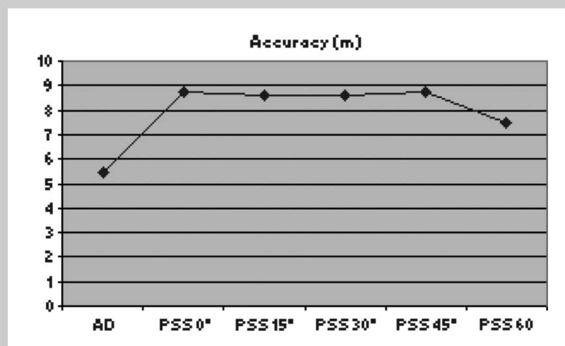

Figure 3. Accuracy means by treatment over time. *α = 0.05.

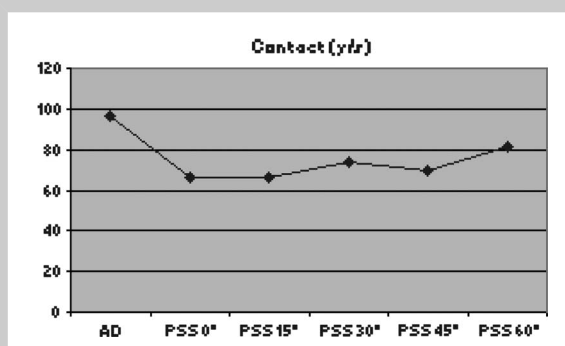

Figure 4. Contact means by treatment over time. *α = 0.05.

Discussion

This investigation was a follow-up study focusing on warm-up treatments on golf performance variables over time. The original study (17,18) focused on the acute effects of passive static stretching on golf driver performance measures and found significant decreases in clubhead speed, distance, accuracy, and consistent ball contact after passive static stretching when compared with a commonly applied active dynamic warm-up with golf clubs (AD). In the present investigation, identical warm-up treatment procedures were followed for acute comparisons at t_0 but performance measures were also taken at t_{15}, t_{30}, t_{45}, and t_{60} minutes post PSS treatment. Swing trials were also reduced from 10 to 3 at measurement intervals for the purpose of ruling out fatigue as a possible mechanism for reduced performance after PSS over time. The means, *SD*s, and *t*-statistics from the original study are included in Table 10 for comparison with the present study's acute performance measures at t_0 in Table 5. The present study's results revealed significant decreases in clubhead speed, distance, accuracy, and consistent ball contact at t_0 similar to the first inquiry. Means, *SD*s, and *t*-statistics for t_{15}, t_{30}, t_{45}, and t_{60} can be referenced in Tables 6–9.

These findings support the golf specific investigation referenced above and the collection of other aforementioned studies reporting acute performance decrements after stretching. The nature of this reduced performance after stretching may be related to the MTU. Rosenbaum and Henning (33) suggest that this decrease in force production is a result of slack in the tendon after stretching exercises. Therefore, less force can be applied to the bone, which results in a correspondingly lower force production for movement and attenuated athletic performance. Cornwell et al. (8) report that observed decreases in performance are a result of the inability of the MTU to store elastic energy. Interestingly, the amount of elastic energy that can be stored in the MTU is a function of the unit's stiffness (22,35). Other authors have demonstrated that tendon compliance and muscle contraction can occur simultaneously in both animals (38) and humans (7). Collectively, these investigations support the theory that a more compliant MTU results in a greater time interval until external force is expressed in powerful athletic movements.

There may also be a neuromuscular explanation to the acute decrease in performance after stretching. Avela et al. (2) measured the reflex sensitivity of skeletal muscles after repeated passive static stretching and more recently (1) using fast passive static stretching. The results of both investigations showed a significant decrease in reflex activity and force production. Kokkonen et al. (24) suggest that such decrements are because of a reduction in the sensitivity of the muscle spindles and theorized that repeated stretching also reduced the number of motor units available because of autogenic inhibition. Knudson et al. (23) hypothesized that a decrease in vertical jump performance was associated with a decrease in neural transmission because they found no change in the kinematics of the movement. Additional investigations provided evidence that reduced force production and performance were attributable to acute neural inhibition from passive stretching that consequently reduced the neural drive to the muscle (1,2,25,33).

In the present study, acute decreases in performance were observed in all performance measures. There are several explanations that apply to these observations. First, it is plausible that the skeletal muscles were normally and sufficiently innervated by the central nervous system but less force was transferred to the golf club due to slack in the tendon. Second, altered neurological activity may have caused the skeletal muscles to fire without synchronization or sufficient action potential thus reducing coordination and force production. A final explanation is that both the transfer of force from the skeletal muscles to the golf club and the neurological system were concurrently impaired due to the PSS treatment. The author supports the later explanation because both force production and neuromuscular coordination are necessary for efficient movement in the full golf swing (6,19,44).

The current study's design tracked golf performance measures acutely and over time at t_{15}, t_{30}, t_{45}, and t_{60} similar to the work of Fowles et al. (15). All dependent performance measures were significantly impaired at t_0, t_{15}, and t_{30}. Interestingly, clubhead speed, primarily a force dependent measure, was not significantly less at t_{45} and t_{60}, whereas impairment continued in other performance measures relating to possible neurological alterations. Thus, it is possible that the mechanical properties of the MTU may have recovered from PSS at a faster rate than the associated neurological changes. That is, a reduction in force-dependent measures (i.e., speed and distance) because of a more compliant MTU appeared to recover by t_{30}, but the neurological measures (i.e., accuracy and distance) representing coordinated movement continued to remain impaired at the t_{30} time interval. Further, the dependent measures associated with coordinated movements, although improving over time, remained impaired at t_{60}. Therefore, theories explaining reduced performance because of a more compliant MTU and an altered neurological state because of stretching may both be accurate explanations; however, they should be contextualized with a time component or consider a recovery curve from stretching when interpreting research findings or designing performance-based warm-up programs. That is, mechanical properties of the skeletal muscle may recover from PSS treatments at faster rates than associated neurological alterations. Figures 1–4 graphically represent the change in performance measures over time.

This inquiry was specific to the golf full-swing driver performance. The full golf swing is a closed kinetic chain in the rotational plane, which categorizes it as a unique skill (27). Therefore, the findings of this study cannot be universally applied to other sport movements. Adequate ROM is paramount for optimal swing mechanics to be learned, improved, and performed (6,44). Other sport kinematics also require specific expressions of flexibility. Therefore, each sport should be evaluated for its specific ROM requirements for optimal performance and the consideration of preventing injury.

In conclusion, the PSS warm-up treatment resulted in significant decreases in driver performance in all dependent measures when compared with AD acutely. Of interest, however, clubhead speed was not significantly suppressed beyond t_{30} while other measures remained impaired. This investigation further supports previous investigations questioning stretch-induced greater ROM and its correlation to performance in athletic movements. It also identifies the time that may be required to recover from such stretching treatments.

Practical Applications

The design of warm-up routines for athletic movements involving high-intensity power output, biomechanical efficiency, and precise coordination, such as golf, should minimize the amount of stretching before practice or competition. It is recommended that these athletes employ an active dynamic warm-up consisting of lower intensity movements progressing toward an ROM required for optimal mechanics in that particular sport. If the athlete has poor mechanics because of lack of flexibility, this training should be performed after a conditioning session, practice, or competition.

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